National Park Service
U.S. Department of the Interior

Inventory & Monitoring Program
Pacific Island Network
Monitoring Plan

Appendix A: Marine Report

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Pacific Island Network (PACN)

Territory of Guam
War in the Pacific National Historical Park (WAPA)

Commonwealth of the Northern Mariana Islands
American Memorial Park, Saipan (AMME)

Territory of American Samoa
National Park of American Samoa (NPSA)

State of Hawaii
USS Arizona Memorial, Oahu (USAR)
Kalaupapa National Historical Park, Molokai (KALA)
Haleakala National Park, Maui (HALE)
Ala Kahakai National Historic Trail, Hawaii (ALKA)
Puukohola Heiau National Historic Site, Hawaii (PUHE)
Kaloko-Honokohau National Historical Park, Hawaii (KAHO)
Puuhonua o Honaunau National Historical Park, Hawaii (PUHO)
Hawaii Volcanoes National Park, Hawaii (HAVO)

http://science.nature.nps.gov/im/units/pacn/monitoring/plan/2004/

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EXECUTIVE SUMMARY

All National Parks in the Pacific Islands border the marine environment and in many cases, they possess submerged lands within their legislated boundary. These submerged lands contain some of the most diverse habitats in the National Park Service system. In the Indo-Pacific region species diversity of the marine habitats may be the highest of any ecosystem (terrestrial, aquatic, or marine) in the entire National Park Service system. Surprisingly, little is known about these habitats for all the Pacific Island Parks; management of submerged lands has lagged behind that of their terrestrial counterparts, and in most Pacific Island parks, marine resources are poorly inventoried and even more poorly monitored/managed.

NPS's prominences on visitor services, which are inherently terrestrial-based, have resulted in less emphasis on management of marine resources. Submerged resources cannot be seen easily, and thus, historically, have received little attention. Additionally, National Parks having marine submerged lands within their boundaries are rare. Of these few instances, very little of the submerged lands are owned by the NPS, resulting in significant management difficulty. There are few cases where Pacific Island National Parks have administrative and management control over submerged lands within their boundary. War in the Pacific National Historical Park (WAPA) located in Guam is the only Pacific Island Park with management control or ownership of all of the submerged land within its boundary. This lack of decision making power over submerged lands necessitates that the NPS work cooperatively with the state and territorial agencies that oversee management of the submerged lands within the parks. In particular, the parks must seek formalized agreements with the State of Hawaii, the Territory of Samoa and the Commonwealth of the Northern Mariana Islands (CNMI) if they are to succeed in their management mission.

The NPS, under the Natural Resource Challenge, has embarked on an ambitious effort to establish a comprehensive, scientifically rigorous, long-term monitoring program for all its natural resources. In the Pacific, the primary goal of NPS marine monitoring should be to gather data and provide evidence that can be used to increase our understanding of causal processes in natural resources and natural resource degradation. The data and evidence gathered can be used to persuade rational and responsible management action and policy. Reaching this objective for all Pacific Island National Parks will be challenging, given the inherent difficulties of working in the marine environment, the lack of trained staff and specialized equipment within many parks, and the paucity of fundamental baseline data about each park's marine resources.

The Pacific Island National Parks span an area greater than the continental United States, making it the largest geographical network in the NPS. This vast geographical distribution means that parks on opposite sides of the network possess different species, and in some cases entirely different marine habitats. In some cases, native species in one area of the network are highly invasive in another (e.g. mangroves), creating further difficulty when attempting to develop specific network-wide management and monitoring objectives. However, marine ecosystems across the Pacific share many common features, specifically the ecological processes (e.g. dispersal, recruitment, growth, calcium carbonate accretion and erosion) that shape them and stressors that alter them. Because of this similarity, network-wide efforts should focus on process and stressor monitoring and management and park-specific efforts should address specific species of concern. This document will build upon these ideas.

All parks in the Pacific contain some significant marine resources. In parks where the boundary ends at the mean high tide line, significant marine resources can include intertidal regions, including beaches used by endangered marine animals for nesting and sea cliffs or other rocky shorelines used by culturally and biologically significant marine animals. Anadromous fish, fish that spend part of their life cycle in the ocean, are also considered to be marine resources, and have been provided special protection under federal law. In some cases, Pacific mangroves are significant coastal features and contain species of plants and animals, some federally endangered, which are unique to the National Park System. In addition to shoreline resources, those parks with marine boundaries have considerable submerged resources. Submerged resources include coral reefs and some associate topographic formations, seagrasses, algae, and other non-coral colonized substrata. Parks throughout the Pacific with submerged resources possess coral reefs. Extensive and well-developed seagrass beds are present primarily in the parks in the Indo-Pacific, the region of the Pacific Ocean to the west of Hawaii.

Nearly all stressors on the marine environment have a terrestrial origin, and most are associated with human activity. As a result, many Pacific Islands National Parks must address similar ecological stressors. Because of the prevalence of marine stressors across the islands, they have been well identified and documented across the Pacific. Nearly all parks have land management issues that result in terrestrial runoff. Runoff-associated issues (e.g. sedimentation, eutrophication, contaminants, freshwater inputs) have been identified as one of the most significant threats to Pacific marine habitats. Harvesting of marine resources is another significant stressor, and few parks in the Pacific have not been subject to intense fishing pressure that has already altered, and in several cases already potentially impaired, marine resources. Climatic stressors are also prevalent across the Pacific Island National Parks. These include ENSO events (El Niño/Southern Oscillation), global climate change, and “heavy weather” (e.g. seasonal sea conditions, tropical cyclones). While most of these “natural” events are outside management capabilities of the NPS, their effects on the marine ecosystem must be taken into account when attempting to monitor other stressors. The importance of invasive species as a significant marine stressor is currently unknown in most Pacific National Parks, but the seriousness of this threat is well demonstrated by several highly visible and very costly cases in Hawaii. Efforts should be placed on collecting baseline data on the identity and distribution of marine invasive species and on their early control or eradication.

Whether because of a unique resource, unusual threats, or logistic difficulty, each park in the Pacific presents interesting challenges for a marine monitoring program. Below, each park is treated in greater detail, including identification of entities with control over submerged lands, of significant marine resources and threats, and of the prospects of conducting a marine natural resource program at the park.

War in the Pacific National Historical Park (WAPA) contains over 1000 acres of submerged land within the park’s boundary. Approximately one third of this land is owned by the NPS and the remaining two-thirds is administered and managed by the park through a Memorandum of Understanding with the territorial government. WAPA has extensive marine resources, including well-developed coral reefs, offshore islands and extensive seagrass beds. Threats to the park are numerous, including sedimentation and other runoff-associated issues, intense fishing, sewage, litter, and the presence of relic WWII military equipment, including large numbers of unexploded ordinance. WAPA has a marine natural resources program that has recently attained critical mass in staffing and has begun the development of a comprehensive marine program. The park's close ties with AMME make it the obvious choice to provide its marine expertise to that park.

American Memorial Park (AMME) has no submerged lands within its boundary. AMME and National Park of American Samoa are the only Pacific Island National Parks to possess native mangroves. Endangered sea turtles have hauled out on the beaches within the park, but there is currently no direct evidence of sea turtle nesting. In addition to threats associated with terrestrial runoff, marine resources at AMME are threatened by the presence of an landfill adjacent to the park (recently closed by the CNMI), light pollution, and high visitor use, all of which may be significantly impacting its marine resources. AMME currently has no on-site natural resource personnel and relies on staff at War in the Pacific National Historical Park for specific resource needs. Logistically, conducting a marine natural resources program at this park will be difficult due to its remoteness and the lack of adequate support facilities both at the park and on the island (e.g., Should use a comma after "e.g." and "i.e." recompression chambers, on-site equipment).

National Park of American Samoa (NPSA) legislative boundary extends to a quarter mile offshore and encompasses areas on four separate islands. The territory maintains ownership of the submerged lands, but what entity actually manages them is currently unclear. Traditionally, local villages have exerted considerable control over adjacent marine resources, and the park will need to consult with the villages, but the territorial government most likely has legal control over the resources and will need to be involved. The issue of ownership and control of the submerged lands at NPSA needs to be resolved. NPSA has numerous critical marine resources, including extensive coral reefs and coral formations, threatened and endangered sea turtles and associated nesting beaches, and marine mammals. Principle threats are associated with rapid population growth and development including fishing, runoff-associated issues such as nutrients from human and animal wastes and other contaminants, landfills and other solid waste issues. In recent years, park staff has noticed what appears to be an increase in the prevalence of coral diseases and bleaching, which may be linked to global warming. NPSA has a marine natural resources program that has reached critical mass in staffing, allowing the park to begin developing a comprehensive marine program.

USS Arizona Memorial Park (USAR) boundary does not extend past the high tide line, but the park does have joint jurisdiction with the US Navy over two submerged vessels: the USS Arizona and the USS Utah. This jurisdiction does not extend to the surrounding submerged land. The two principle marine resources in the park (i.e. the sunken vessels) are primarily cultural resources. Both vessels are heavily biofouled, and this encrusting layer of organisms may be aiding in the preservation of the vessels and consequently should be monitored. Pearl Harbor is a heavily altered and impacted embayment, and the marine community present at USAR is a reflection of these altered environmental conditions. USAR does not have a marine natural resources program. Its close proximity to considerable marine expertise should make outsourcing both economically feasible and relatively simple to perform.

Haleakala National Park (HALE) boundary ends at the high tide line. HALE's primary marine natural resources are its extensive and somewhat isolated intertidal regions, comprised of beaches used by nesting endangered sea turtles and monk seals and its exposed rocky shores that possess a diversity of intertidal organisms, including endemic limpets (opihi), a culturally significant invertebrate. Because of the relative isolation of HALE's marine resources, threats are believed to be few and relatively minor. Harvesting of marine resources occurs within the park, and litter may be significant in some areas. HALE currently has no marine natural resource staff, and is sufficiently isolated from other parks with appropriate staff that development of an internal NPS marine monitoring program will be difficult. Some on-island expertise exists, but the park will most likely need to look off island to meet its foreseeable needs. Logistically, HALE will be a very difficult park in which to conduct marine monitoring. Its marine resources lie along an exposed shoreline, where working conditions are hazardous. This will limit the scope of any work to be conducted within this park.

Kalaupapa National Historical Park (KALA) legislative boundary extends a quarter mile offshore, and in addition to submerged lands, encompasses three offshore islands. All submerged land within the park is owned and administered by the state of Hawaii. KALA has threatened and endangered sea turtles that forage within the park and endangered monk seals that use the beaches. Coral reefs are well developed in sheltered areas and are comprised of a basalt boulder/coral habitat elsewhere. Endemic Hawaiian limpets (opihi) can be found along the park's extensive basalt shorelines. KALA faces significant issues associated with upland development, including sedimentation and other runoff-associated issues. While fishing is generally not considered a problem (except for opihi), commercial fishing vessels have been observed operating within the park. KALA has a marine natural resources program, but staffing issues have resulted in a program that has yet to reach critical mass and is still searching for direction. Several unique challenges associated with the park (e.g. isolation, housing, administrative complexities) will continue to impede the full development of this program as an internal NPS entity. Considerable marine expertise exists in the state, and the park's relative accessibility (a single daily flight) makes outsourcing of a marine monitoring program conceivable but potentially costly. Regardless, expertise within the park to guide the program may prove crucial to the success of its marine program.

Puukohola Heiau National Historical Park (PUHE) administrative boundary extends into the water and encompasses Pelekanhe Bay. All submerged lands within the park are owned and managed by the state of Hawaii. The park has culturally significant marine resources, including an unusual brackish water pond and associated submerged ancient Hawaiian temple (heiau). Pelekanhe Bay is a pupping area for black tipped reef sharks and at least two other shark species also occur within the park. PUHE has numerous threats associated with upland development and visitor use. Runoff and associated nutrients, contaminants, and sediments are a significant problem. A heavily used road traverses the park and is most likely a significant source of pollution. A major marina facility is located upstream of the park and, with its recent expansion to handle larger vessels, may present significant future problems. Heavy visitor use and illegal dumping in the park creates a significant solid waste problem. PUHE has no marine natural resources program, but its close proximity to KAHO may allow the park to draw upon the expertise at that park.

Kaloko-Honokohau National Historical Park (KAHO) contains approximately 600 acres of submerged land within the legislative boundary, but all marine lands are owned and administered by the State of Hawaii. KAHO has numerous critical marine resources including extensive coral formations, threatened and endangered sea turtles, spinner dolphins, and turtle nesting beaches. Large ancient Hawaiian fishponds are both a natural and cultural resource. Threats to park resources are many and varied. Adjacent land use is affecting groundwater and runoff. One of west Hawaii's only marinas lies within the park boundary, resulting in significant boating (e.g. groundings, contaminants) and recreational issues (e.g. fishing, SCUBA diving). The fishpond is threatened by at least two marine invasive species: red mangroves (*Rhizophora* sp.) and a species of red algae (*Acanthophora spicifier*). KAHO has a coral reef program, but has yet to reach critical mass in staffing. Once fully staffed, KAHO will have the capabilities to conduct a comprehensive marine monitoring program and because of its proximity to PUHE, PUHO and to a limited extent HAVO, it may be able to provide support to these parks.

Puuhonua O Honaunau National Historical Park (PUHO) boundary ends at the high tide line. PUHO has sea cliffs in the southern portion of the park. These basalt cliffs may be a nesting site for sea birds, may contain significant cultural resources such as burial caves, and are ideal habitat for Hawaiian limpets (opihi). The park staff has also observed threatened and endangered sea turtles in the area, but has not witnessed nesting on the park beaches. Evidence suggests that monk seals may have historically used the area. PUHO has numerous threats related to upland development and visitor use. Upland residential areas are on septic systems and pesticides once used at the park have been observed in anchialine pool sediments, but the presence of pesticides in marine sediments is unconfirmed. Fishing pressure is believed to be high, but quantitative data is lacking. Visitor use of beaches may be affecting their use by sea turtles but data is again lacking. PUHO has no marine natural resources program, but its close proximity to KAHO may allow PUHO to draw upon the expertise at that park.

Hawaii Volcanoes National Park (HAVO) boundary ends at the high tide line, limiting its significant marine resources to coastal intertidal areas, particularly to beaches that are used by threatened and endangered seas turtles. Because of the isolated nature of the park's marine resources, threats are relatively few and predominately minor, the most significant of which is the presence of fishermen along the coast. In addition to harvesting marine resources, the presence of humans near turtle nesting beaches may impact turtle nesting success. Currently, HAVO has no on-site marine natural resource staff. Considerable marine expertise is located on-island, including in nearby Hilo, making outsourcing a feasible possibility. Logistically, HAVO will be a difficult park in which to conduct marine monitoring because its marine resources lie along an exposed shoreline, where working conditions are extremely hazardous. This will limit the scope of any work to be conducted within this park.

Ala Kahakai National Historical Trail (ALKA) is a 175 mile trail corridor traversing the West Hawaii coast from Upolu Point down to Ka Lae and up to Hawaii Volcanoes National Park, and is adjacent to significant and unique marine resources. The marine resources within the Ala Kahakai trail system include those within NPS units designated boundaries (i.e. PUHE and KAHO) and those that are adjacent (i.e. PUHO and HAVO). A combined Comprehensive Management Plan and EIS (CMP/EIS) is currently being developed and will identify significant resources and key issues associated with an extensive trail system that travels through areas with differing jurisdictional sources. Significant marine resources along the West Hawaii coast include those with both natural and cultural origins. Shoreline and intertidal areas offer habitat for marine flora and fauna, some of which are harvested for food or are important to Hawaiian heritage. Pristine waters can be found nearshore, with extensive reefs with coral and algal species that offer complex habitat for other species. Endangered and threatened species, including marine mammals and sea turtles frequent these waters and shoreline areas. Threats for this park unit are many and varied, including beach erosion, invasive species, light pollution, marine recreational activity and sea level increases, to name a few. One of the greatest threats in the marine environment may come from land use of the surrounding watershed. Presently, ALKA does not have a marine natural resources program, however, one of the parks that it traverses, KAHO does have an established marine resources program. ALKA park management will also consult with and encourage communities and land owners along the trail as well as native Hawaiians and volunteer trail groups to participate in monitoring these resources.

The PACN is in a good position to develop a comprehensive marine monitoring program, but because of the highly specialized and sometimes hazardous nature of the work, many difficulties still need to be overcome. Since Fiscal Year 2000, five parks in the Pacific have received base funding increases to develop marine focused natural resource programs. These programs will be fundamental to the network's monitoring effort, because they are the primary source of marine expertise within the Pacific Islands National Parks. These marine programs are spread across the Pacific, creating logistic difficulties with conducting comprehensive marine programs at most parks, even those with marine programs. Working in the marine environment has significant inherent challenges, requiring highly specialized training, equipment, and expertise as well as a critical mass of staff to be successful. In many places, this critical mass has not yet been achieved, and may never be achieved (e.g. Hawaii). This may require parks to out source marine natural resource work, which could be expensive depending upon the location of the park and the availability of local expertise.

This document is intended to be an overview of the current knowledge of marine resources in all Pacific Island National Parks. While we've attempted to touch on all major topics, due to the broad scope of this document, each topic is addressed only superficially. Highlighting the gaps in our current knowledge, which in many cases are considerable, we hope to focus initial efforts toward achieving the NPS marine monitoring goals. This document has been assembled with the valuable insights of many individuals, including numerous experts on a variety of marine issues, but ultimately any shortcomings are attributable entirely to the principle author.

INTRODUCTION

SCOPE OF TOPIC AREA

Marine environments, as defined by this workgroup, include all salt water habitats existing primarily at or below the mean high tide line, their associated biological organisms, their physical and biotic environments, and the processes that affect them. This work group has restricted its focus to habitats occurring within or near the boundaries of Pacific Island Network (PACN) National Parks, and thus comprise predominantly shallow water, tropical marine habitats including coral reefs, algal reefs, sand flats, seagrasses, intertidal areas, including mangrove stands, coastal fishponds, and in one case, a marine lake. Excluded from this report are anchialine pools, freshwater and low salinity environments (less than 20 parts per thousand (ppt) salt water; e.g. streams, marshes). Where information is not immediately available on habitats within park boundaries, information on similar adjacent habitats was sought.

BACKGROUND

The PACN is unique within the Pacific West Region in that it is geographically, climatically and ecologically distinct from the rest of the region and nation. Many marine issues important to the mainland coastal parks in the Pacific West Region and elsewhere are not relevant to the national parks in the PACN, and, accordingly, we have focused on PACN issues.

This report attempts to be inclusive in addressing environmental and monitoring issues. In addition to issues currently relevant to parks, this report will address emerging issues; emerging issues are those that currently are not affecting parks, but may become significant in the foreseeable future.

Unlike their counterparts in Florida and the Caribbean, National Parks in the PACN have not had long-term monitoring programs for their marine resources. While numerous non-NPS monitoring programs exist throughout the Pacific region, few of these include areas within National Parks. Regardless, the information collected from these non-NPS monitoring programs is valuable to the PACN parks and should be incorporated into the development of NPS monitoring programs and decision making.

Congress has mandated that the NPS engage in scientifically credible natural resource management including development of a long-term monitoring program (National Parks Omnibus Management Act of 1998). This act, while not explicit, extends to management of submerged marine resources. Currently, most PACN National Parks lack the essential baseline data necessary to effectively and appropriately manage their marine resources. Because of inherent variability of biological communities from year to year, long-term baseline data are necessary for scientifically-informed, sound management.

Because of their location in the tropical Pacific Ocean and their insular nature, parks within the PACN share many environmental issues and concerns. Consistent network-wide monitoring approaches offer an opportunity to collect comparable data among PACN parks and other appropriate sites, allowing for analysis of Pacific-wide marine environmental trends. Therefore, this report will examine marine environmental issues and stressors from a network perspective.

All parks have environmental resource issues specific to their location and condition. In some cases, environmental stressors that occur across network parks may manifest themselves in different or similar ways at different parks. Collection of data on these stressors can provide park-specific information to guide park-based natural resource managers. In other cases, parks may possess very specific management concerns; therefore, this document will also address park-specific issues.

Members of the local community access and use park marine resources and are significant stakeholders. For any management program to succeed, these communities must be involved in the resource management discussion process. This involvement is particularly important in regions where indigenous cultures are still intact, as within the PACN. To the extent allowed by law, efforts will be made to include members of the community in all aspects of the process, from the initial development of the park-specific monitoring programs to the collection and interpretation of results from monitoring and their application to management decision-making.

MONITORING GOALS AND OBJECTIVES

The primary goal of the National Park Service (NPS) marine environmental monitoring is to gather data and provide information that can be used to increase our understanding of causal mechanisms and processes affecting natural resources and their degradation. This information can be used to inform and recommend clear and responsible management action and policy.

Data mining is the critical first step in discovering and supplying existing baseline information on marine resources in and near parks and related monitoring activities. In addition to providing contemporary information, it is important to provide as much historical information as can be uncovered, and information from unimpaired areas, in order to adequately address the Ghost Community phenomenon and the Sliding Baseline syndrome. Because of the relative paucity of work conducted in the marine environments of the PACN parks, wide latitude must be given to the information collected and its source; data mining must extend to studies conducted exclusively outside of the boundaries of PACN parks. Efforts must be made to find all information relevant to the park areas; at present much more information collection is needed.

The ultimate goal of any management program is to preserve the natural resources in a manner that will leave them unimpaired or unaltered by human activity, in a 'natural' or 'pristine' state. Since few pristine environments remain, the ideal is practically unattainable and this interpretation will vary (see discussion above). Nonetheless the NPS is dedicated to maintaining or restoring the lands and waters in and around parks to conditions that are as natural and unimpaired as possible.

A problem arises when managers do not know what determines an "unimpaired" or "natural" condition. When examining this concept, we must consider the "shifting baseline syndrome." Pauly (1995) coined this term when referring to fisheries scientists and their perception or idea of what is considered a 'normal' stock size and how that changes over time. The idea with a "shifting baseline" is that each individual considers what they first observed (start of career or as a child) in a natural environment to be in 'good' condition. Then, in subsequent human generations the baseline of what is considered natural in the ocean shifts further and further from the truly unimpaired natural state that occurred prior to human influence. Every effort will be made in this plan to address the "Sliding Baseline" syndrome.

Another important concept to consider and that should be considered in any long term monitoring program is the concept of 'ghost' communities (Dayton et al. 1998, Tegner and Dayton 2000). Different reasons may contribute (e.g. fishing, natural disturbance) to the loss of key species or structuring community components (e.g. sea otters). Once these components are missing, what remains are assemblages and "ghosts" of the community with no way to quantitatively assess community function. Quite often these communities may be functioning at a "damaged" or impaired state.

Our interpretation of ecological roles in a snap shot of an ecosystem may not be an accurate representation of how an ecosystem functions and may not provide an accurate basis for making natural resource management decisions. The removal of a species from a community might not have an immediate or discernable effect and could be complicated with other effects such as weather or fishing. In some cases, if a species is removed to local extinction, the state of the former ecosystem may not be restorable (Pitcher 2001). To make meaningful decisions, long-term observations of an ecosystem are necessary to discern both natural and anthropogenic effects. Any effort to gain historical representations of past community dynamics would assist with an increased and better understanding of the marine ecosystems in the PACN.

Understandably, management of natural resources might require decision-making based on (for our part) a partial understanding of an ecosystem. In this case, decision-making should be based on the concept of adaptive management and the ability to base and change decisions as our knowledge of ecosystem dynamics increases.

LEGISLATION AND POLICY

As a federal agency, the NPS operates under a hierarchy of legislative mandates, including federal laws, executive orders, Department of the Interior and NPS policies and directives, and state and territorial regulations. Further, management of submerged resources is complicated by jurisdictional or administrative issues that are generally more complicated than similar issues on land. These complexities require the NPS to cooperate with numerous and often overlapping federal and local agencies to achieve its objectives.

ADMINISTRATIVE CONTROL OF SUBMERGED LAND

Unlike emergent, dry, or fast lands, submerged lands and their resources are often not owned or administered by the NPS. This situation creates a unique problem when implementing or enforcing management decisions. Some National Parks in the PACN have legislated boundaries that extend into adjacent waters, while others do not. Parks with submerged lands within their boundary (regardless of ownership or control) include: NPSA, WAPA, KALA, KAHO, and PUHE. Parks with adjacent marine waters, but whose boundaries end at the mean high tide line include: HAVO, PUHO, AMME, and HALE. ALKA, at present, is still trying to determine trail alignment, but historically followed 282 kilometers of the shoreline on the island of Hawaii. USAR has administrative control over two submerged vessels, the USS Arizona and the USS Utah. They have no legal jurisdiction over any other submerged lands or objects.

The State of Hawaii owns and administers the submerged lands below the high tide line within three miles (4.8 kilometers) of all fast land within the state. The jurisdiction falls under the Department of Land and Natural Resources.

The marine area of NPSA encompasses 2,550 acres with 32 kilometers of coastline. The park boundary extends 0.4 kilometers offshore (6 fathom depth) with 3 coastal units. The NPS has 50-year lease agreements with 8 villages that share boundaries with the park units. The offshore waters for all the park units are under the American Samoan government's jurisdiction but administered by the local villages. The Department of Marine and Wildlife Resources manages and protects marine resources.

The Commonwealth of the Northern Mariana Islands (CNMI) also owns and administers the submerged land adjacent to American Memorial Park (AMME). There are 133 acres of land affiliated as a memorial park to CNMI, with the NPS offering its services towards technical and planning assistance only. The 133 acres are owned and under CNMI jurisdiction. However, the 133 acreage was leased to the Department of Defense (DOD) who, in turn, re-leased the land that falls within AMME's border back to the CNMI government. The present jurisdiction of the park ends at the mean high tide mark so all marine waters are adjacent to the designated AMME boundary.

WAPA has 6.4 kilometers of coastline and 1002 acres of submerged resources divided between two shorefront units within its boundary. Approximately one third of the submerged lands within War in the Pacific NHP (WAPA) are owned by the NPS; the remaining lands are owned by the Territory of Guam, which, through a Memorandum of Understanding (MOU) with the NPS, has ceded administrative control of these lands to WAPA. A condition of the MOU, however, ensures the continuation of traditional subsistence fishing within the park in accordance with territorial fishing regulations. The situation in Guam is further complicated because some submerged lands within WAPA are owned by the Department of Defense (U.S. Navy), which has it own resource mandates and MOU with the territorial government.

INVENTORY & MONITORING PROGRAM (NATURAL RESOURCE CHALLENGE)

The Natural Resource Challenge (NRC), initiated in 1999, is an action plan for preserving natural resources through the National Park Service (NPS). The NRC assisted NPS to establish 32 Inventory and Monitoring networks, which includes 270 National Parks. In the Networks, parks are grouped that share geographical and natural resource characteristics. The Inventory and Monitoring (I&M) Program is designed to first complete basic inventories of natural resources in parks, on which to base long-term monitoring efforts. Monitoring programs are based on monitoring critical parameters (Vital Signs) within each network to incorporate into natural resource management and decision-making. "Vital Signs are measurable, early warning signals that indicate changes that could impair the long-term health of natural systems" (NPS 2003). Major challenges addressed in this plan pertinent to the marine environment include native and endangered species, non-native species, environmental stewardship and water quality. The vital signs monitoring plan and this appendix address these issues.

INTERNATIONAL LAWS

- Convention Against International Trade in Endangered Species (1975): The Convention Against International Trade in Endangered Species (CITES) is an international agreement ensures that international trade does not threaten the existence or survival of endangered or threatened species. It regulates the trade of species listed as endangered or threatened by the country of origin, the importing country, or any countries that the species might travel or pass through.
- International Convention for the Prevention of Pollution from Ships (1973): The International Convention for the Prevention of Pollution from Ships (MARPOL) is an international treaty regulating the disposal of waste generated by vessel operation and includes regulations for oil, noxious liquids carried in bulk, harmful substances carried in packaged form, sewage from ships, garbage from ships, and air emissions.

FEDERAL POLICIES & LEGISLATION

Federal Legislation

- Rivers and Harbors Appropriation Act (1899): This act prohibits construction of any bridge, dam, dike or causeway over or in any navigable waterway of the US without Congressional approval. It also prohibits (without Congressional approval) the building of any wharfs, piers, jetties and other structures, and it requires that any fill or excavation be approved by the Chief of Engineers. Authority to issue permits was given to the Corp of Engineers and the Fish and Wildlife Coordination Act provides authority to the US Fish and Wildlife Service to review and comment on effects to fish and wildlife associated with activities proposed or undertaken by the Corp of Engineers.

- NPS Organic Act (1916): The NPS Organic Act of 1916 established the National Park System "…to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations." While long considered a dual mission, court decisions (e.g. Southern Utah Wilderness Alliance vs. Dabney) support only a single mission: conservation (=preservation) of natural and cultural resources. According to the courts, without conservation of these irreplaceable resources, the perceived second mission could not be accomplished.
- Sport Fish Restoration Act (1950): Also known as the Dingell-Johnson Act, it was created for management, conservation, and restoration of fishery resources. This act authorizes the Secretary of the Interior to provide financial assistance for fish restoration and management plans. Furthermore, the Sport Fish Restoration Program was created under this Act and was funded by revenues from taxes on fishing equipment. Amendments included the enactment of excise taxes with the Wallop-Breaux Amendment in 1984, inclusion of wetlands conservation in 1990, and creation of boat-related waste disposal facilities in 1992.
- National Environmental Policy Act (1969): The National Environmental Policy Act (NEPA) forms the framework of modern environmental policy for all federal projects, agencies and employees and it is mandated that all federal actions take into account the effects of the proposed activity on the environment. NEPA also provides for public input into the federal process.
- Marine Mammal Protection Act (1972): The Marine Mammal Protection Act (MMPA) protects the many mammals that live in the world's oceans. This legislation is the basis for policies preventing the harassment, capture, injury, or killing of all species of whales, dolphins, seals, and sea lions, as well as walruses, manatees, dugongs, sea otters, and polar bears.
- Coastal Zone Management Act (1972): The Coastal Zone Management Act (CZM) established a voluntary national program within the Department of Commerce to encourage coastal States and territories to develop and implement coastal zone management plans that would define the boundaries of the coastal zone, identify uses of the area to be regulated by the State, the mechanism for controlling such uses, and broad guidelines for priorities of uses within the coastal zone.
- Federal Water Pollution Control Act (1972): This legislation, more commonly known as the Clean Water Act, is aimed at restoring and maintaining the chemical, physical and biological integrity of the nation's waters. This Act authorized the EPA to prepare comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries and improving the sanitary condition of surface and underground waters. Due regard was to be given to improvements necessary to conserve waters for public water supplies, propagation of fish and aquatic life, recreational purposes, and agricultural and industrial uses. A number of other provisions found in the current Act were adopted prior to 1972. Section 404 of this act gives authority to the U.S. Army Corp of Engineers as the primary federal agency with responsibility for wetland management.

- Endangered Species Act (1973): The Endangered Species Act provides broad protection for species of fish, wildlife and plants that are listed as threatened or endangered in the U.S. or elsewhere. Provisions are made for listing species, as well as for recovery plans and the designation of critical habitat for listed species. The Act outlines procedures for federal agencies to follow when taking actions that may jeopardize listed species, and contains exceptions and exemptions. The Endangered Species Act also is the enabling legislation for the Convention on International Trade in Endangered Species of Wild Fauna and Flora, commonly known as CITES.
- Magnuson-Stevens Fishery Conservation and Management Act (1976): This act recognizes that marine and anadromous fish are valuable and renewable natural resources and that they have been damaged by loss of essential habitat and overfishing. This law finds it necessary to implement a national program for the conservation and management of fisheries to prevent overfishing, rebuild stocks, and ensure conservation before irreversible harm occurs. While this act does not appear to cover species that occur exclusively within non-federal waters (e.g., on coral reef flats), it specifically applies to anadromous fish species regardless of their location and should offer protection for offshore species when their juveniles use nearshore habitats such as reefs.
- Redwood Amendment to the 1970 Act for Administration (1978): This amendment, reaffirmed the mission of the park service to protect, manage and administer its areas and required the NPS to let nothing cause "…derogation of the values and purposes for which these various areas have been established…." This act required the NPS to examine, address and protect parks from all impacts, including impacts originating on non-park lands adjacent to NPS-owned land (including non-federal lands). This amendment was in response to the several court cases concerning logging on private lands adjacent to Redwood NP (e.g. Sierra Club v. Department of the Interior).
- Park System Resource Protection Act (1990): This Act has been successfully used in instances of vessel groundings and provides specific protection to all natural resources. While this Act does not authorize the removal of a vessel, it does provide legal means for recovering costs for response and recovery for “all necessary actions to prevent or minimize the destruction, loss of, or injury to park resources.” This act is especially powerful in this particular situation given the challenges associated with maritime law in the USA and legal difficulties that can arise with grounded vessels.
- National Invasive Species Act (1996): This Act directly mandates federal agencies to manage marine invasive species. This includes activities (among others) to understand and minimize economic and ecological impacts and to develop and carry out environmentally sound control methods to prevent, monitor, and control nonindigenous species.
- Sustainable Fisheries Act (1997): The Sustainable Fisheries Act of 1997 (P.L. 104-297) addresses the issues associated with “overfishing, protection of fish habitats, and Pacific Insular Areas.” The Act’s purposes include “promotion of catch-and-release programs, non-wasteful development of underutilized fisheries, and protection of fish habitats”; and its policies concern “efficiency, bycatch, and Pacific Insular Areas.”

- National Parks Omnibus and Management Act (1998): Commonly called the "Thomas Bill", the National Parks Omnibus and Management Act (NPOMA) clarified the role of the NPS as a conservation and science agency. Among the items it specifically mandated were the establishment of an inventory and monitoring program to obtain baseline information on natural resources, the development of a broad, rigorous scientific research program, and the hiring and training of scientists within the NPS. Additionally, NPOMA granted protection for key natural resources, particularly geological/paleontological resources within the parks by restricting sensitive information from release under the Freedom of Information Act.
- Coral Reef Conservation Act (2000): This act was created to preserve, sustain, and restore the condition of coral reef ecosystems, while promoting wise management and sustainable use of these valuable marine resources. This act is responsible for the formalization of the U.S. Coral Reef Task Force, and provided funding to achieve the objectives of this act.
- Shark Finning Prohibition Act (2000): The Shark Finning Prohibition Act (H.R. 3535) is an amendment to the Magnuson-Stevens Fishery Conservation Management Act that eliminates the practice of shark finning. Shark finning refers to the practice of removing fins and usually discarding the remainder of the body.
- Marine Turtle Conservation Act (2003): The Marine Turtle Conservation Act (H.R. 3378) was enacted to "assist in the conservation of marine turtles and the nesting habitats of marine turtles in foreign countries by supporting and providing financial resources for projects to conserve the nesting habitats, conserve marine turtles in those habitats, and address other threats to the survival of marine turtles." This act is important because many of the sea turtles found in waters of the US and its territories travel large distances and often in international waters.

Executive Orders

- E.O. 13089. Coral Reef Protection (1998): This document provided federal protection to coral reefs within the U.S., its territories and commonwealths such that federal agencies may not fund or participate in actions that can have a detrimental impact on coral reef ecosystems. This Executive Order also established the Coral Reef Task Force.
- E.O. 13112. Invasive Species (1999): This Executive Order commits the US government to preventing the introduction of invasive species, controlling existing populations of invasive species, and minimizing the economic, ecological and health impacts associated with invasive species. This Executive Order addresses invasive species in all territorial lands and waters of the United States.
- E.O. 13158. Marine Protected Areas (1999): This Executive Order commits the federal government to the protection of marine resources through the development and protection of Marine Protected Areas (MPAs). This Executive Order extends to all federal lands and water over which the U.S. exercises jurisdiction.
- E.O. 13186. Responsibility of Federal Agencies to Protect Migratory Birds (1999): This Executive Order was issued to direct Federal Agencies to develop Memorandum of

Understanding (MOUs) with the USFWS to increase the conservation and minimize the take of migratory birds. Seabirds are included in this Executive Order.

NPS LEGISLATION

Park Enabling Legislation

Each park, except USAR, has enabling legislation that describes the primary purpose and mission of the park. (USAR operates under a Memorandum of Understanding with the US Navy.) Park Enabling Legislation often contains specific directives requiring the conservation of key natural resources, including marine resources. Resources specifically named in the Enabling Legislation will require special attention from the park, and may require park-specific monitoring and/or research to accomplish the legislated mandate. Additionally, park enabling legislation may mandate specific strategies for park resources that require maintaining these resources in such a way that may be inconsistent with the objectives of this monitoring plan. This is most often manifested in the form of maintaining a cultural landscape (e.g., maintaining vegetation as it occurred at a certain time period or in a certain condition) and will supercede other management objectives for the park.

NPS Management Policies

NPS Management Policies were revised in 2000 and contain extensive guidance on Natural Resource Management (see Chapter 4 of the NPS Management Policies Handbook). All monitoring activities must fall within the framework of these Management Policies. Difficulties may arise in that few policies are specific to marine environments or resources and require creative interpretation and use of policies by resource managers.

Park-specific Management Polices

Some parks will have park-specific management policies required to meet the mission or conditions of their enabling legislation. These park-specific policies must be considered in the development of a monitoring plan and in the management action decision process. Park-specific management policies may include the Superintendent's compendia.

Director's Orders and Other NPS Documents

Several DOI and NPS directives and documents provide guidance and support for natural resource management. Two examples are cited here:

- Memorandum to Secretary of the Interior from the Solicitor (16 April 1998): This memorandum analyzes the Secretary's legal duty to protect parks from activities on non-NPS land adjacent to park boundaries. While not explicit in the Redwoods Amendment, this memo provides support for involvement in natural resource issues lying outside the park boundary.
- D.O. 55 (2000): D.O. 55 further clarifies language within the NPS Organic Act and the 1970 Act for Administration including the Redwood Amendment by reiterating the single mission of the NPS: to preserve resources. This Director's Order also clarifies what

constitutes impairment, park resources and values, and provides guidance for decision making, including requiring scientific data in accordance with the National Parks Omnibus and Management Act.

REGIONAL CONTROLS & REGULATIONS

Activities conducted in the marine environment will need to meet many state regulations, especially where lands are not under the ownership or control of the NPS. In addition to whatever local permits may be required, many activities conducted in the marine environment will require permitting from the Army Corp of Engineers under section 404 of the Clean Water Act. This permit requires a federal consistency review by all relevant state agencies for compliance with local water quality regulations. Familiarity with these regulations is essential for a NPS marine monitoring program to succeed.

American Samoa

- American Samoa Code Annotated (ASCA): Natural Resources and Environmental Ecosystem Protection and Development (Title 24). The next four chapters that follow below are in title 24 and pertain to the marine environment (http://www.asbar.org/Newcode/Title%2024.htm).
- Environmental Quality Act of 1972 (ASCA 24.02). The Environmental Quality Act contains standards for water quality. This program is administered by the American Samoa Environmental Protection Agency/Environmental Quality Commission.
- Office of Marine and Wildlife Resources (ASCA 24.03): It is the policy of American Samoa "to preserve, protect, perpetuate and manage the marine and wildlife resources within the territory." Some of the Public Laws contained within this policy are a prohibition on drift gill net fishing, and requirements for reporting by fishermen and processors (including a duty).
- American Samoa Coastal Management Act of 1990 (ASCA 24.05). The American Samoa Coastal Management Act mandates "the establishment of a system of environmental review, along with economic and technical considerations, at the territorial level intended to ensure that environmental concerns are given appropriate consideration in the land use decision-making process." This program is administered by the Economic Development Planning Office/American Samoa Coastal Management Program (EDPO/ASCMP).
- Endangered Species (ASCA 24.07): In this chapter, a commission was recommended to be formed to identify both endangered and threatened species for the Territory and to suggest programs for conservation, protection and propagation of these species.
- Executive Order (2001): This executive order was issued by the Governor to ban the use of scuba equipment while fishing in American Samoan waters. It was believed that this practice contributed to the decline of reef fish abundance.

Commonwealth of the Northern Mariana Islands (CNMI)

- Coastal Resources Management Act (PL 3-47): Established the Coastal Resources Management Office (CRMO) and regulation for activities permitted in ‘Wetland and Shoreline Areas of Particular Concern’ (APCs). Regulations protect mangroves and critical wetland habitat and protect endangered or rare species.
- Fish and Game Endangered Species Act (PL 2-51): Established the Division of Fish and Wildlife and contains regulation regarding fish and wildlife management. This act also authorizes the designation of endangered species and critical habitat.
- Environmental Protection Act (PL 3-23): Established the Division of Environmental Quality. This act also includes regulations for water quality certification and waste water discharge.
- Public Land Exchange Act (PL 5-33): Includes framework for land acquisition for public purposes including wetland protection.
- Fisheries Act (Proposed in 2003): The Fisheries Act (HB 13-178) proposed to provide management, enforcement and data collection authority for commercial fisheries in CNMI waters.
- Regulations on fishing gear include the following. Talaya nets and scoop/landing nets must be licensed, registered and have identification tags. All other nets are prohibited in the CNMI and include surround, gill, drag, purse, seine and drift. All use of lay gill nets for fisheries is banned. Fish weirs are not allowed in CNMI.
- Regulations on fishing include the following. There is no take allowed of snails, marine gastropods, trochus or sea cucumber. Collection of coral (live and dead) is not allowed, except dead coral on the beach for Afuk. Aquarium fish sale or export is also not permitted except for personal use by hook and line capture.
- Managaha Marine Conservation Act (2000): The Managaha Marine Conservation Act (MMCA) was established by the CNMI Legislature to protect the island and the surrounding waters for recreational and cultural purposes. These waters were established as Class I no-take marine protected areas with human activity based on permit basis. The Division of Fish and Wildlife (DFW) is authorized to monitor natural resources and enforce protection of these waters and land.
- Other Marine Protected Areas include the following. PL 10-18 in 1997 established Sasanhaya Fish Reserve on Rota, PL 12-46 in 2001 established Bird Island Marine Sanctuary on Saipan, PL 12-46 established Forbidden Island Marine Sanctuary on Saipan in 2001, and in 2000 DFW Regulations that established Lighthouse Reef Trochus Reserve and Lau-Lau Bay Sea Cucumber Reserve. Fishing and anchoring are restricted in MPA’s.

Guam

- The Endangered Species Act of Guam (1979): The Endangered Species Act of Guam (Guam Public Law 15-36) protects both locally and federally listed endangered species on Guam.

- Revised Guam Water Quality Standards (2001): Public Law 26-32 was enacted to amend the Guam Environmental Protection Agency water quality standards.
- Guam Soil Erosion and Sediment Control Regulations (2000): The Guam Soil Erosion and Sediment Control Regulations (P.L. 25-152) regulates "soil erosion and sedimentation resulting from the construction of sub-divisions, industrial and commercial developments, highways and other activities requiring excavation and filling" through a permit and review process.
- Guam Territorial Seashore Protection Act (GC §13410 enacted by P.L. 12-108): Under this act, coral can be removed only by permit from the Department of Agriculture. This same act regulates fishing mesh size used in coastal waters as well as illegal fishing methods.
- An Act to Establish Rules and Regulations for the Control of Fisheries by the Department of Agriculture (1997): This act (P.L. 24-21) instituted territorial fishing regulations and mandated the establishment of Marine Protected Areas.

Hawaii

- Hawaii State Constitution, Article XI, Section 1: Conservation & Development of Resources. Section 1 states that "the State and its political subdivisions shall conserve and protect Hawaii's natural beauty and all natural resources, including land, air, mineral and energy sources, and shall promote the development and utilization of these resources in a manner consistent with their conservation and in furtherance of the self-sufficiency of the State."
- Hawaii State Constitution, Article XI, Section 7: "The legislature shall provide for a water resources agency which, as provided by law, shall set overall water conservation, quality and use policies; define watersheds and natural stream environments; establish criteria for water use priorities while assuring appurtenant rights and existing correlative and riparian uses and establish procedures for regulating all uses of Hawaii's water resources. (Add. Constitutional Convention 1978 and election November 7, 1978)"
- Hawaii State Constitution, Article XII, Section 9: Environmental Rights. Section 9 states that "each person has the right to a clean and healthful environment, as defined by laws relating to environmental quality, including control of pollution and conservation, protection and enhancement of natural resources."
- State of Hawaii Administrative Rules 11-54: These rules mandate the conservation of coral reefs in class AA waters. Marine waters are classified as AA (in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-caused source or actions. To the extent practicable, the wilderness character of these areas shall be protected. No zones of mixing shall be permitted in this class) or A.
- Hawaii Revised Statutes §171-58.5: Sand, dead coral or coral rubble are allowed to be collected are protected from commercial purposes and can only taken for personal purposes seaward of the shoreline.

- Hawaii Revised Statutes §188-68: This statute prohibits any person to take any live stony corals, including live reef or mushroom corals in Hawaiian waters under state jurisdiction. It is also unlawful to take any rock to which living marine species are attached. Sale of some corals are prohibited in Hawaii.
- Hawaii Revised Statutes §205A: This law restricts anchoring on coral reefs.
- Shark Finning Prohibited (2000): Shark finning was prohibited by law with HB 1947 that bans landing of any shark fins in the State.

GENERAL ECOLOGICAL CONTEXT

GEOGRAPHY

All the PACN network parks are located on tropical islands in the Pacific Ocean. Eight of the parks are in the Hawaiian Islands in the Central Pacific between 19 and 22 degrees North latitude. HAVO, KAHO, PUHE, PUHO, and the recently designated ALKA are on the island of Hawaii, the youngest of the main Hawaiian Islands at the southern and eastern end of the archipelago. HAVO is located on the southeast slope of Hawaii Island, where it extends from sea level to the summits of Kilauea and Mauna Loa Volcanoes. The newly designated Kahuku unit of HAVO is positioned on southern Mauna Loa and extends down both the eastern and western flanks of the volcano. PUHE, KAHO, and PUHO are coastal parks of the western side of the island. KAHO is centrally located with PUHE to the north and PUHO to the south. HALE is on Maui, the second youngest Hawaiian Island. HALE extends from sea level to the summit of East Maui. KALA is on a peninsula projecting from the north shore of Molokai, centrally located in the main Hawaiian Islands. USAR is within Pearl Harbor on southern or leeward Oahu. Two PACN parks are situated in the western Pacific Ocean between 13 and 15 degrees north latitude in Micronesia. WAPA is on the western side of the island of Guam and AMME is on the west coast of Saipan, one of the Northern Mariana Islands. NPSA is on the Polynesian islands of American Samoa, approximately 13 degrees south latitude. One unit of NPSA is on the island of Tutuila, and three others are on Tau, Ofu, and Olosega of the Manua Island group 96 km (60 miles) east of Tutuila.

GEOLOGY

The parks of the Western Pacific (WAPA, AMME) are on the islands of Guam and Saipan which have long-extinct volcanoes. These islands have complicated geologic origins involving both volcanism and subduction of the Marianas Trench. Hence, the northern half of Guam and portions of Saipan have limestone substrates elevated above a weathered volcanic base. WAPA units are on the volcanic substrates of the southern half of Guam, and at least one unit includes elevated limestone caps.

The islands of American Samoa and Hawaii are oceanic volcanic islands arising from hotspots. The oldest of the Samoan Islands are dated at more than two million years, but there was volcanic activity between Tau and Olosega approximately 150 years ago (Whistler 1994). In Hawaii, HALE protects the summit of the inactive Haleakala Volcano and its impressive crater, which is the result of stream erosion, the merging of Kaupo and Keanae Valleys, and subsequent volcanic activity. KALA encompasses the Kalaupapa peninsula, formed on the north shore of

Molokai during the Pleistocene (MacDonald and Abbott 1970). The volcanoes on both Molokai and Oahu are extinct.

The five parks on Hawaii Island are on active or dormant volcanoes. A significant portion of HAVO is covered with recent lava flows that are sparsely vegetated. HAVO also contains the rift zones and summit calderas of both Mauna Loa and Kilauea Volcanoes, two of the most active volcanoes on earth. PUHO is on prehistoric pahoehoe flows of Mauna Loa, and PUHE substrates are old weathered soils of Kohala Volcano. All substrates of KAHO are flows from Hualalai Volcano less than 10,000 years old, including one sparsely-vegetated lava flow dated at 1,000-3,000 years (Moore et al.1987).

ELEVATION GRADIENTS

Among the Hawaiian parks, HAVO and HALE have the greatest elevational range, extending from sea level to the summits of tall volcanoes >3,000 m (>10,000 ft) in elevation. KALA has an elevational range from sea level to almost 1,220 m (4,000 ft) elevation. The three parks of leeward Hawaii Island are coastal parks and extend upslope to an elevations less than 100 m. ALKA is also in the coastal lowlands of western and southern Hawaii Island.

Among the three Western Pacific parks, AMME is restricted to coastal lowlands on the western shore of Saipan. WAPA includes both coastal units and inland sites on the slopes of Mt. Alifan and Mt. Tenjo, with one unit extending above 305 m (1,000 ft) in elevation. NPSA is composed of four units; Ofu and Olosega are largely coastal but the Tutuila and Tau units range from sea level to 491 m (1,610 ft) and 966 m (3,170 ft) elevation, respectively. The planned expansion of NPSA on Ofu and Olosega will include the summits of both islands, which are 499 m (1,621 ft) and 639 m (2,096 ft) respectively.

RAINFALL AND CLIMATE

The largest two Hawaiian parks, HAVO and HALE, include within their boundaries several climatic zones with a range of rainfall regimes. HAVO contains two of the four rainfall minima of Hawaii Island, the Kau Desert with mean annual rainfall <750 mm and the interior lands of Mauna Loa. The highest mean annual rainfall within the park is found in Olaa Tract, a rain forest with >4,000 mm per year (Giambelluca *et al*. 1986). In general, the eastern windward portion of HAVO has high rainfall, which diminishes upslope, particularly above the trade wind inversion layer near 1,830 m (6,000 ft) elevation. The upper elevations of the park are moist to very dry, and the summit of Mauna Loa receives on average <500 mm precipitation. The leeward, western portions of HAVO are in rain shadows of Mauna Loa and Kilauea summit, and are typically dry.

HALE also has a range of climates, as it extends from sea level on the windward, eastern slope of Haleakala to the summit of East Maui. This park also includes lands in the leeward rain shadow of Haleakala, down to 1,220 m (4,000 ft) elevation. Annual precipitation in the park varies from 1,250 mm in the Crater, the southern slope, and Kaupo Gap to >6,000 mm on the upper northeastern slopes of Haleakala. KALA, on the north shore of Molokai receives 1,000 mm of precipitation annually at sea level and >3,000 mm at the upper elevations of Waikolu Valley (Giambelluca *et al*. 1986). The USAR on Oahu is located within Pearl Harbor on the dry leeward side of the island in an area than has on average 600 mm rainfall per year.

The four Hawaii Island parks are in relatively low rainfall areas with constant warm temperatures and pronounced daily wind patterns of land and sea breezes (Blumenstock and Price 1967). KAHO has a mean annual rainfall of approximately 600 mm and a seasonal climate with higher rainfall during summer months (Canfield 1990a). The climate of PUHO is similar to that of KAHO, with mean annual precipitation of 659 mm. PUHE is located within one of the four rainfall minima of the island of Hawaii and receives less than 250 mm of rain annually (Giambelluca *et al*. 1986). Because ALKA covers a large linear coastal transect along West Hawaii, the rainfall pattern is variable.

The climate of Guam and the Northern Marianas (CNMI), including Saipan, is warm, wet, and tropical. Temperature varies between 90 and 70 degrees Fahrenheit. Relative humidity is high, often exceeding 80% and seldom falling below 50%. The rainfall pattern is strongly seasonal with a wet season from July to November and a pronounced dry season from December to June. Average annual rainfall of the Marianas is 2,160 mm (Baker 1951), and on Guam the annual mean is 2,175 mm (Mueller-Dombois and Fosberg 1998). Typhoons are yearly events, which occur during the monsoonal wet season. Trade winds blow from the northeast, but easterly and southeasterly winds prevail during several months in the spring (Baker 1951). Because Guam and the Marianas are relatively low islands, there is no pronounced rain shadow effect, and leeward shores are not drier than those of the windward sides (Mueller-Dombois and Fosberg 1998).

NPSA has a warm tropical climate with little seasonal variation in temperature. Rainfall is high in the four units of the park. On Tutuila, annual rainfall averages 3,200 mm (at the airport), and may be even higher on the upper mountain slopes within the park. Rainfall is seasonal with greater monthly means from October to May and a dry season from June to September. Hurricanes are occasional but not annual events (Whistler 1994). Tau Island unit is only about 96 km (60 miles) east of Tutuila and shares its warm and wet tropical climate. Tau average rainfall is more than 2,500 mm per year and is highest in December. The dry season is June to September, and droughts sometimes occur on the island (Whistler 1992).

CONCEPTUAL MODEL – PACN MARINE ECOSYSTEMS

The marine ecosystems in the PACN are complex systems with scores of interacting components, many of which are difficult to quantify. Conceptual models are an effective and simple portrayal used to highlight ecological components and their pathways in these marine ecosystems. Please see Chapter 2 of the PACN Monitoring Plan that provides in depth background material on the development of conceptual models. The PACN marine conceptual model is depicted by Figure 1. Drivers are represented by the blue boxes. Pink ovals depict the stressors. Yellow diamonds represent pathways that link stressors and ecological attributes. The green octagons are the ecological attributes (i.e. vital signs). The following text provides background information as well as explains the reasoning for linkages.

A purpose of the PACN marine model was to create a generalized ecological model of the marine ecosystems that could be used to address current management issues. It was not possible to include all stressors and their pathways; however, we tried to incorporate, include and portray major issues and concerns affecting parks across the PACN. Furthermore, this model is an ideal tool to help formulate monitoring questions by illustrating major stressors, their pathways and ecological attributes (i.e. vital signs) that we can monitor for detection of change. The model presented in this report is ever dynamic, a work in progress, dependent on emergent concerns and evolving issues, and therefore should be periodically reviewed.

INTRODUCTION TO CONCEPTUAL MODEL

The Pacific Ocean is the largest body of water on Earth, covering over 400 million square kilometers; its greatest depth, 10,924 meters, occurs in the Mariana Trench near Guam and Saipan. The Pacific includes many diverse environments extending towards the Polar Regions. Over 30,000 islands occur in the Pacific representing independent nations, some with strong affiliations to other nations (e.g. Commonwealths, Affiliated States), or Territories or Colonies of other nations. Politically, most island nations in the Pacific are relatively young in age, having gained independence since World War II.

The Tropical Pacific is a narrow band of water and land centered on the equator between the Tropics of Cancer and Capricorn (23° N and 23° S). While usually considered warm, this region can range in temperature from below freezing to over 38°C. The world's only tropical glacier (Mt. Wilhelm in Papua New Guinea) occurs in the Pacific Ocean. Most areas, however, are noted for warm, humid weather, moderated by oceanic breezes. Rainfall is usually considered high, but this varies with latitude and land elevation. Ocean temperature is warm, often above 30°C, but in some areas can be considerably cooler (e.g. upwelling regions, such as along the west coast of Central America).

Primary ocean currents within the Pacific form two gyres, one north of the equator and one to the south. The northern gyre flows clockwise, flowing north to Japan in the Western Pacific, east along the southern shores of Alaska, south down the coast of North America and west just north of the equator. A complimentary current runs south of the equator in a counter-clockwise direction. These currents are responsible for the ocean-wide biogeographic patterns of the Pacific. The Pacific Ocean can be divided into at least three distinct regions: Indo-Pacific, Central, and Eastern, characterized by biogeographical and environmental features.

Centered on Indonesia, the Indo-Pacific is a warm region of high marine species diversity (Briggs 1999) with many islands, island chains and archipelagos. Moving away from this region - in any direction - results in a decline in species diversity. This decrease in diversity is usually attributed to individual species life history patterns and physical factors such as water temperature and current patterns that can limit larval dispersal and survival (Stoddart 1992). Guam and Saipan are located in this region. The Central Pacific, whose boundaries are not firmly established, is a region generally occupying the Pacific tectonic plate. Many of the islands in this region are isolated (by current patterns) from the Indo- and Eastern Pacific. Islands, island chains and archipelagoes are less common than in the Indo-Pacific and, in general, more isolated from each other. Biodiversity is lower than in the Indo-Pacific. The Eastern Pacific is often characterized as a region of upwelling of deep, nutrient rich waters. Ocean temperatures are colder relative to the Indo- and Central Pacific. Islands are fewer in number; comparatively few oceanic islands exist between Hawaii and the mainland United States, a distance of ~ 5600 km. Eastern tropical Pacific warm water species tend to be different from Central and Western Pacific species, and many have affinities with Caribbean species. Expected species diversity at PACN parks, ranging from highest to lowest is: Guam and Saipan, American Samoa, Hawaii. Expected endemism at PACN parks (highest to lowest) is: Hawaii, American Samoa, Guam and Saipan.

Compared to terrestrial ecosystems, marine ecosystems display relatively low species endemism from island to island. This also includes isolated island groups such as Hawaii, where marine endemism is quite high at 20% but lower than that observed on land (50-100%, depending on the taxonomic group). Endemism also increases with distance from centers of diversity.

Smaller scale, localized ocean circulation patterns have been shown to be very important to local community dynamics. Small scale gyres transport important larvae within islands and island groups, sometimes creating localized populations that are separated from other conspecific populations within an island groups or between islands. The understanding of localize oceanographic conditions on coral reef communities is, at current, limited, but will be critical to the future management of these marine resources.

MARINE HABITATS FOUND IN PACN

Coral Reefs

Coral reefs are found in shallow tropical seas and are constructed primarily by hermatypic or reef-building corals. Corals are colonial marine invertebrates that photosynthesize via algal symbionts within their tissues and deposit extensive calcium carbonate skeletons that eventually form the foundational matrix of the ecosystem. Coral reefs are diverse and complex marine ecosystems, often drawing comparisons to tropical rainforests in terms of species numbers and complexity of interactions (Connell 1978, Birkeland 1997).

Seagrass

Seagrasses are a relative small group of marine flowering, plants that occur in predominately shallow, soft-bottom coastal waters and estuaries (Kirkman 1990). Seagrasses usually inhabit shallow mud or sand bottom areas and are important in stabilizing sediments reducing suspended material within the water column and improving coastal water quality. Seagrass meadows often serve as nursery grounds for ecologically or economically important coral reef species and are critical to the long-term health of the coral reef ecosystem.

Algae

Most tropical marine algae occur in the intertidal zone, on the reef flat, or other shallow reef zones. Algae are important components of the coral reef ecosystem; microscopic zooxanthellae, symbiotic within coral tissues, are essential to reef building corals; without these microalgae there would be no reef development. Many macroscopic algae are food for herbivorous fishes and invertebrates; some algal macrophytes precipitate and incorporate calcium carbonate which is important in the construction and stability of coral reefs.

Soft Bottom

Soft-bottom ecosystems consist of sand or mud and are ubiquitous, often found interspersed among extensive coral-dominated reefs or patch reefs. These accumulations of sediment typically result from bioerosion of carbonate reefs and coralline algae, along with input of sediment that run off the land during rainy periods. These sedimentary habitats may have low species diversity relative to structurally heterogeneous coral reefs, which may be increased in high nutrient conditions (usually from anthropogenic sources). Most species living in soft substrates are specialized to deal with shifting sediments. The common species are infaunal, living in the sediments (e.g., worms, clams, snails) and these benthic species assemblages are often correlated with sediment size. Some coral reef animals utilize soft-bottom areas extensively for feeding (e.g. goat fish, some snappers).

Mangroves

Mangroves are found in tropical intertidal zones, estuaries and sheltered coastlines at the convergence of freshwater and salt water. Mangrove forests consist of salt water tolerant plant species and provide wetland habitat and refuge for many different species (Ewel et al. 1998). Species diversity in mangroves is typically high and mangrove habitat also serves as a nursery for many coral reef species. This ecosystem serves as a filter, and traps considerable amounts of sediments before they can be transported onto the coral reef, thus improving water quality. Like coral reefs, mangrove stands protect shorelines from waves and erosion. Mangroves have adapted to a limited range of tolerance in water quality parameters and may therefore serve as good indicators of coastal change (Blasco et al. 1996, Field 1995).

Intertidal

The intertidal zone is the transitional habitat between land and sea that lies between the mean high and low tide lines. These areas may be exposed to disturbances, mainly from wave action or desiccation stress. Intertidal areas can be soft-bottom (e.g., sandy beaches, mudflats) or hard-bottom (e.g., basalt or limestone benches, boulders or cobbles, and rubble). Tidepools, small salt water pools on the shoreline that are periodically refreshed with seawater, act as a nursery for many coral reef species. Intertidal species still have strong links to the ocean, including dispersal of gametes (eggs and sperm), embryos and larvae or spores in coastal waters. Intertidal plant and animal species are highly specialized to survive the extreme environmental conditions found in this habitat.

EXTERNAL DRIVERS AND ECOLOGICAL STRESSORS

Jenny (1980) identified six major categories that ecological drivers/stressors could be broadly classified into and they include: climate, organisms, relief/topography, parent material, time and human activity. Changes in magnitude or direction of these drivers result in changes in the biological community, often resulting in different species composition, diversity or patterns in population abundance or dispersion. Human activity can significantly alter the nature or magnitude of a Natural Driver, creating an unnatural type or level of stress on a community and subsequent changes in its structure or function. In the PACN parks there are sources of drivers/stressors that could fall under each of these major headings identified by Jenny (1980), however, we modified and adapted them to highlight areas of concern for the marine environments in the PACN. Major external sources of ecological drivers/stressors in the Pacific Island marine ecosystems emphasized in this model include climate change, natural disturbances (including effect of weather), terrestrial human activity and coastal development (and its effect on water quality), direct human impact resulting from marine human activity (including fishing pressure and nearshore recreational activities), invasive species and disease. Because human activity is diverse and has such a profound effect on marine communities, in this model we have separated the actions into two distinct categories, one originating from terrestrial and land development activities and its effect on the marine environment and another originating from human activity in the marine environment (e.g. fishing, marine recreational use). In the marine conceptual model, in Figure 1, the major drivers are represented by the blue boxes while the more specific stressors (described under each driver) are represented by the pink ovals.

Climate change

Global climate change is an ongoing natural phenomenon recorded throughout the planet's geological history. However, human activity, resulting in increased atmospheric carbon dioxide concentrations, has been linked to elevated air and sea temperatures, ozone depletion and concomitant increases in ultraviolet radiation, glacial recession, sea ice melting, increases in sea level, and changes in seawater chemistry. Increased sea surface temperatures will have a significant effect on marine ecosystems, notably coral reefs and mangroves. Increases in atmospheric carbon dioxide would lower sea water pH and reduce calcification rates for corals, thus significantly impacting reef accretion rates. Global warming has been identified as one of the principal threats to coral reef ecosystems in the Pacific and other oceans, and in particular effects from rising temperatures and increased ultraviolet radiation. Please see the Air Quality and Climate topical workgroup reports for more in depth detail on these and other climatic influences. We have highlighted important aspects that are of current concern to the marine parts of PACN parks.

Increased temperature: While most tropical marine species are well adapted for living at high temperatures, these species are generally sensitive to relatively small changes in ocean temperature. Any tropical marine species can only survive within a narrow temperature range and a small increase in sea temperature can be lethal to species such as corals that could under-go protein shock and result in bleaching events.

Ultraviolet Light Radiation (UV): Ultraviolet light is present in all shallow and coastal waters, but can be particularly damaging to cells at lower latitudes. Biological organisms either produce chemical compounds (e.g., microsporine amino acids) or otherwise counter UV effects by seeking shelter from UV radiation (Kuffner 1999). Many marine animals are capable of sensing light in UV wavelengths and some have UV coloration, suggesting that UV may play an important role in animal behavior and species interactions. Photosynthetic zooxanthallae in corals have UV absorbing compounds with concentrations that are generally inversely proportional with water depth.

Natural disturbances

Natural disturbances in the marine environment can originate from action by other organisms or as a result of change in the environment from geological or climatic changes. Disease and invasive species could be considered a natural disturbance, but, they will be considered separately in this report. Climate conditions, both short- and long-term, can have significant effects on the marine environment. Atmospheric conditions alter the physical and chemical properties of ocean water, including surge, currents, temperature, nutrients, light availability, salinity. Three major sources of natural disturbances potentially affecting PACN marine environments include extreme weather events (e.g. tropical cyclones) and the El Niňo/Southern

Oscillation (ENSO) patterns and freshwater surge. Please see the Air Quality and Climate topical workgroup reports for more in depth detail on these and other climatic influences.

Extreme weather events: Extreme weather events (e.g. tropical cyclones) can have significant effects on the marine environment. Strong winds and storm surges associated with tropical cyclones can physically damage reefs and seagrass beds (Rogers 1993). Rainfall increases terrestrial runoff and associated fresh water influx, sedimentation and nutrient enrichment to reefs. These effects may be pronounced if reefs are weakened by bleaching events, disease or population outbreaks.

ENSO: This atmospheric and oceanographic phenomenon is characterized by increases in sea surface temperature, particularly in the Eastern Pacific and changes in rainfall patterns and biological processes throughout the Pacific basin and well beyond. Changes in sea surface temperature have significant effects on the development and survival of virtually all coral reef organisms. El Niňo also has dramatic effects on many other organisms, including humans, in diverse environments. Mass bleaching events have been linked to El Niňo/ENSO (Hoegh-Guldberg 1999, Glynn 2000). The frequency and strength of tropical cyclones may be amplified with ENSO events.

Freshwater: Influxes of low salinity water (as occurs in proximity to stream mouths and along many coastal areas off volcanic islands due to increases in surface or groundwater runoff) can significantly alter the chemical properties of seawater, particularly properties associated with osmotic balance between organisms and their surrounding environment, affecting the metabolism and the physiology of plants and animals.

Terrestrial human activity and coastal development

Land development in the coastal zone can and often does have both direct and latent effects on nearshore environments by changing topography, area available for heavy precipitation to infiltrate the soil, waterways or groundwater, water use and availability, and surface and ground water flow. Land development generally increases runoff and associated marine sedimentation. Development also creates sources of domestic and industrial pollution since development usually occurs upland or upstream from reefs, where contaminants enter coastal waters with surface or ground water flow. Major effects of terrestrial activity (i.e. habitat destruction, watershed alteration & erosion) influencing PACN parks’ nearshore waters include pollutants & toxins, eutrophication (including sewage), erosion and sedimentation.

Alterations of coastal habitat: Degradation and loss of habitat occurs with coastal development in the water or on the coastline. Habitat degradation and alteration result from the construction of piers, harbors, sea walls, airports, and navigational aids. On the Kona coast of the island of Hawaii there has been increased population expansion resulting with increased development in the past several decades. In American Samoa, a similar increase in population has also occurred, and its effects may be expressed with the loss of habitat. For example, approximately 5 acres of mangroves are removed per year in American Samoa (Bardi and Mann, technical report no.45). Concern arises when habitat is altered or lost. Environmental impacts of development vary depending on the feature and site location. While most areas have regulations governing coastal zone construction these are often inadequate or poorly enforced.

Pollutants and toxins: Toxins are natural or man-made compounds that, at different concentrations (usually elevated above natural levels), have adverse effects on organisms.

Toxins may accumulate at elevated concentrations in the sediments or tissues. Because of their aqueous environment, marine organisms are particularly susceptible to many toxins, and may be adversely affected at levels much lower than thresholds set for human health. Marine larvae, especially coral larvae, may be especially susceptible of toxins occurring in low concentrations. Some pollutants may act at sublethal levels, interfering with reproduction and growth. Pollutants, once in the food chain can bioaccumulate, potentially reaching levels in top carnivores that becomes a human health concern.

Eutrophication: Nutrients are inorganic or organic chemicals required by organisms for maintenance of physiological processes including metabolism and photosynthesis. Macronutrients are typically considered to be nitrogen and phosphorous compounds. Many micro- or trace nutrients (e.g., zinc, silicate) are required for the function and health of microbes, plants and animals. Nutrients occur naturally or anthropogenically. Anthropogenic sources include agricultural fertilizers and other nutrients that enter the ocean by runoff from land sources including sewage outfalls. Excess nutrients are absorbed more easily by simpler organisms (e.g., macro-algae) than complex organisms (e.g., vascular plants, seagrass). Nutrients allow them to multiply more quickly and could facilitate a phase shift.

Sedimentation: Sedimentation is the settling of soil and other sediment from the water column onto the bottom. Sediment sources can be allochthonous or of terrigenous (land) origin, or autochthonous, originating from marine environments. Sedimentation is a complex phenomenon affected by terrestrial, and to a somewhat lesser extent, marine sediment inputs to reefs, and local climate, weather, and oceanographic conditions. Sedimentation has direct and indirect impacts on reef organisms. Sedimentation can stress or bury benthic organisms with lethal or sublethal effects. Land-derived sediments, generally a result of runoff, can often be accompanied by inputs of nutrients or pollutants. Input or resuspension of sediments can cause the release of nutrients or pollutants that are either adsorbed to sediment particles or trapped in sediment porewater. Pollutants may then enter the food web, bioaccumulate, and create unpredictable effects. Sedimentation has been described as one of the primary threats to Pacific coral reef ecosystems. Anthropogenic effects of sedimentation on coral reefs can result from poor agricultural practices and logging (Burke et al. 2002, McCulloch et al. 2003).

Marine human activity

Marine (water) human impacts in PACN parks include effects from fish removal, destructive fishing methods, aquarium fish collecting, debris (lost gear), reef trampling, anchor damage, and groundings. Hawaii alone has approximately 6 million visitors a year that participate in marine-based activities. These activities, while important to the tourism industry of the Pacific Islands, are also conducted by the local people, often with more intensity. Because of this, the potential magnitude of these impacts could b significantly increased.

Fisheries harvest: In this report, fishing refers to the harvest of any marine organism from its environment, for any purpose – personal use, subsistence or commercial -- regardless of whether the organism is released after capture. While often considered by some to have few negative effects, catch and release fisheries, and fisheries in general, significantly alter the behavior of, or cause injury or death to individuals and lead to tremendous changes in community structure and function as fished species become absent from an area. Most coastal environments throughout the world today are in actuality “ghost communities,” wherein the complete set of species (and their important roles in ecological processes) originally inhabiting an environment is no longer intact. Indeed most coastal marine communities are a mere shadow of their former states. Since baseline conditions have not been scientifically established for many marine areas or fished populations, we know, at least anecdotally, that in many places there has been a shifting or sliding of ecological baseline conditions from those known by previous generations of coastal peoples. Certainly, fishermen universally lament the long-standing and perhaps in some cases permanent changes, including the complete absence, or the reduction in numbers or sizes of numerous fished species. Impacts of fishing on habitat condition are just as important. In the Pacific, a wide diversity of marine species are fished for consumptive uses and fishing has well documented, significant impacts on ecosystem structure and function, and on the condition of resources. This trend is the case for coral reefs and all other marine ecosystems regardless of place, depth or habitat type. Fishing is increasingly documented as being the principal threat to Pacific coral reefs and other marine ecosystems worldwide.

Aquarium fish collecting: Aquarium fishing is a subset of fishing addressed above but receives special attention here because of its increased potential for ecological damage. Aquarium fishing tends to focus on small individuals, often juveniles, potentially removing individuals that should be entering the breeding population. This fishery is significant in Hawaii, particularly along the Kona coast where approximately fifty permits have been issued and just over 100 target species are sought (Tissot and Hallacher 2003). Aquarium fishermen are required to report monthly catch, but it is believed that the majority of these are not filed and actual catch statistics are underestimated (Tissot and Hallacher 2003). At this time, aquarium fisheries are not significant sources of catch in the Mariana Islands or American Samoa.

Destructive fishing methods: Destructive fishing methods are fishing techniques that cause considerable, direct damage to the environment. These include the use of dynamite or chlorine bleach, both of which cause high collateral mortality in other organisms and can cause extensive physical damage to the reef structure. While most areas of the Pacific have specific laws prohibiting destructive fishing methods, these practices can and probably do continue to occur, but instances are rare for the most part in or near the Pacific Network Parks.

Reef trampling (anchor damage/groundings): Fishing and other recreational activities can result in mechanical damage to marine habitats. Anchors and boat groundings kill corals and remove seagrasses. Waders, whether for swimming or fishing, trample reefs. All of these activities reduce the three dimensional structure of reefs, which reduces the diversity and abundance of marine life.

Debris: Conventional fishing methods can result in considerable equipment being lost in the water, including nets, lines, traps and hooks. Endangered and threatened sea turtles and marine mammals are often victim to these entanglements. Net and line can entangle wildlife, drowning turtles and other marine mammals or wrap around the bottom and abrade corals, algae, and other invertebrates. Fish can be trapped in derelict gear (i.e. ghost fishing). Debris from other recreational activities, such as trash, can be a visual eyesore and can be hazardous to marine life if ingested. The number of small, plastic debris has increased in frequency in the Pacific Ocean and in the Hawaiian Islands (McDermid and McMullen in press).

Invasive species

Invasive species are capable of establishing within and significantly altering ecosystems. When released from the environmental and biological controls of their native habitats, these species are often able to out-compete and exclude native species, potentially driving the native species to local or global extinction (e.g. brown tree snake on Guam). Marine invasive species are receiving increasing scientific and public attention. There are now severe outbreaks of some species on some reefs in the Pacific, and these species, their ecological consequences, and possible means of control are subjects of active research. The magnitude and geographic extent of this problem is not adequately known in the marine environment for coral reefs (Coles et al. 2004, Paulay et al. 2002) or the intertidal zone (Baumgartner and Zabin 2004). The Bishop Museum and the University of Hawaii Botany Department both have programs that are examining some of these issues for the Hawaiian Islands.

Population outbreaks: Some native species undergo large population fluctuations, sometimes resulting in seemingly abnormal, extremely high densities of a given species on reefs. These population explosions can have a detrimental impact on corals (with cascading effects through reef ecosystem), especially if the species experiencing the population explosion are corallivorous predators such as the Crown-Of-Thorns Seastar (COTS), *Acanthaster planci*, or snails of the genus *Coralliophila*. COTS are voracious predators on corals and when their populations are at outbreak levels, constitute a significant biological disturbance, causing the destruction of large tracks of reef. Evidence suggests these outbreak events may be natural and cyclic, but anthropogenic links associated with terrestrial runoff and eutrophication have also been hypothesized (Birkeland 1982).

Disease

Until recently little attention has been given to diseases of marine organisms in the Pacific and their ecological consequences. Both are poorly understood. Diseases of corals and turtles have recently received considerable scientific attention, as the occurrence of these diseases appears to be increasing worldwide.

Coral disease, currently more prevalent in the Atlantic Ocean and Caribbean Sea than the Pacific regions, has lead to significant coral mortality on some reefs, with some areas having a mortality of just under 40% for living corals during the later half of the 90s (Porter et al. 2002). There are 18 known coral diseases with pathogens resulting from bacteria, cyanobacteria, fungi and protists (Sutherland et al. 2004, Richardson 1998). Of these 18, only 5 are confirmed by Koch’s postulates (the same process that causation of human disease undertakes).

Very little is known about mechanisms that trigger and execute disease and its transmission. In many cases, it is very difficult to establish direct causal relationships, but progress has been made. The occurrence of fibropapilloma tumors in Hawaiian sea turtles has been found to coincide with a marine leech. Some disease is suggested to originate from anthropogenic activity (Sutherland et al. 2004). Abiotic stressors that have been linked with disease in coral reefs include elevated temperature, eutrophication, sedimentation, pollution, fecal contamination, solar ultraviolet radiation, poor water quality, and precipitation (Sutherland et al. 2004, Richardson 1998, Bruckner et al. 1997).

Coral diseases prevalent in the Indo-Pacific include black band disease, white plague-like disease, skeletal anomalies (including tumors), skeletal eroding band, and yellow-blotch band disease (Sutherland et al. 2004). American Samoa, the Main Hawaiian Islands and the Mariana Islands have all documented some or other of these diseases. While sedentary animals and plants might be better monitored for presence of disease, for sea turtles, there have been regions that have a lower frequency of occurrence of tumor infestations than others.

ECOLOGICAL ATTRIBUTES

The ecological attributes included in the current marine conceptual model are primarily the set of vital signs proposed for monitoring marine ecology in the PACN. In the model (Figure 1) they are represented by the green octagons.

Benthic Landscape

Relief and topography have a significant effect on marine ecosystems. Like altitudinal gradients in terrestrial communities, the composition of marine ecosystems changes with depth. In addition, physical relief (often measured as rugosity), is important to diversity and abundance of marine organisms. Physical relief along with other living components, are important aspects of invertebrate and algal community dynamics and fish assemblages (Jokiel et al. 2004, Friedlander et al. 2003).

In marine systems, the composition of the parent material can affect species distributions and community composition. Some marine species will only settle on specific surfaces, and differences between basalt and calcium carbonate substrata are well documented. In some cases, marine organisms respond to chemical cues from other organisms, and the absence of these organisms from the substrata will preclude settlement (e.g. coralline algae and coral invertebrate recruits). For example, some coral species respond to the presence of calcareous algae, some species of nudibranch will only settle in the presence of specific coral species. Marine fish assemblages are influenced by their physical habitat and live coral cover (Friedlander et al. 2003, Friedlander and DeMartini 2002), components of the benthic landscape.

Disturbances, either natural or of human origin, impact all aspects of ecosystems at a landscape level. These impacts can include habitat, successional stages, structural differentiation, water quality/quantity, wildlife variety and quantity and scenic variability. Important factors to consider include whether the distributions of large scale habitat types (inside and immediately outside the parks) change over time (i.e. lagoons, algal/coral reef cover) and whether reef erosion/accretion is occurring.

Intertidal Landscape Pattern

At the landscape level biological communities in the intertidal zone are closely associated with substrate type (e.g. sandy beaches, basalt boulders). The distribution of biological flora/fauna can be measured by their association with their physical surroundings. Changes in intertidal biotic assemblages and/or substrate types are often indicators of environmental change in the coastal zone. Change can be either natural or anthropogenic, and patterns in this change can provide clues to the type and source of the perturbation.

Marine Recreational Use

Levels of marine recreational activity are important to monitor especially in areas where the activity may be associated with observable damage to the marine environment. Damage can result from groundings/anchorings, trampling, and debris associated with fishing, camping/picnicking and cultural practices. Damage, especially the physical damage that reduces the three dimensional structure of a coral reef, can have cascading effects through a coral reef community. Intertidal areas may also be heavily impacted due to their close proximity to foot traffic traveling in/out of the water.

Fisheries Harvest

Comprehensive fisheries data comprises two distinct data types: fishery independent and fishery dependent data. In order to examine fishery effects on the environment, both data are needed. Fishery dependent data is catch or harvest data, specifically, what and how many fish are removed from the marine environment. While this may not necessarily correlate with population levels of fishery species still in the wild, it can give an indication of the population status, and specifically whether it is changing. The actually levels of these target species in the wild is fishery independent data and is discussed in the next section.

Invertebrate community structure & dynamics

Trophic interactions cover a number of types of relationships that occur among organisms. Among these are: mutualistic symbiosis (e.g., the fundamental interdependence of reef-building corals on nutrients obtained from populations of algal cells [zooxanthellae] living within the tissues of coral hosts, which in turn provide their animal waste products as nutrients to the algae), herbivory (or primary consumption by animals of photosynthetically derived plant material and energy), predation (secondary or higher order consumption of animals by animals) and other forms of symbiosis (e.g., parasitism, commensalism). Trophic interactions are often considered as one of the primary mechanisms shaping community structure.

Coral reef ecosystems are centers of biodiversity because of the complexity of habitat available to different organisms. The reef provides substrate for sessile organisms to attach and an increased surface area for motile organisms to live or feed. In part, due to their biological complexity and because they are sessile, corals are very sensitive to changes in their environment. Changes in surrounding water quality, turbidity, or the presence of contaminants or pollutants have an impact on corals and ultimately the associated community. The proximity of coral communities to coastal areas makes them susceptible to sources of anthropogenic stress (Willkinson 2000, Jokiel and Cox 1996).

Intertidal community structure & dynamics

While intertidal species are adapted to survive extreme environmental conditions (e.g. temperature, desiccation), they are vulnerable to anthropogenic effects resulting from coastal land-use and development, and therefore may be important indicators of environmental change. Tidepools serve as nurseries for some coral reef species. Most PACN parks contain an intertidal zone, either adjacent to or within their boundary. The intertidal region also has cultural significance for many Pacific Islanders.

Algae and vascular plant community structure & dynamics

Within the PACN, marine primary producer-based communities include coral, seagrass, mangrove and macroalgae.

Many macroscopic algae are food for herbivorous fishes and invertebrates; some algal macrophytes precipitate and incorporate calcium carbonate, contributing to the construction and stability of coral reefs. Some algae compete directly with corals for habitat. In the presence of high nutrients, algae may overgrow, kill, and exclude corals. Some marine invasive algae threaten coral reefs in the Main Hawaiian Islands and constitute a serious management issue (Smith et al. 2002).

Seagrass are important shallow water communities. They filter sediments from the water, stabilize bottom sediments, and reduce shoreline erosion (Kirkman 1997). Seagrass meadows act as nurseries for coral reef and fisheries species. Like land plants, seagrass photosynthesize and are sensitive to changes in light. Low primary productivity in seagrass can affect harvested fish species (Bulthuis 1983).

Mangroves are a unique marine community in that they are a transition community from land to sea, containing plants and animals from both ecosystems. They have high species diversity. Mangrove plants are adapted to living in seawater and provided numerous ecological services. Mangroves serve as a nursery habitat for many coral reef species. They act as filters, trapping sediments before they can be transported onto the coral reef, thus improving nearshore water quality. Mangrove stands protect shorelines from waves and erosion, and in some cases accrete land.

Fish assemblages

Fish serve a variety of ecological functions that affect ecosystem productivity and sustainability. Fish assemblages can act as indicators of general reef health and provide an early warning of environmental stress and ecosystem change. Overexploitation (fishing or aquarium trade collection) of either a piscivorous or corallivorous species may have cascading effects on other members of the assemblage (Carr et al. 2002, Friedlander and DeMartini 2002). Monitoring an assemblage or a guild of species may offer a more reliable indicator of environmental change than monitoring a single species (e.g. CRAMP).

Focal invertebrate population dynamics

Focal or indicator species can be monitored at a more intense level than the rest of the community. Monitoring at the population level provides more detail on selected species of interest, potentially providing an early warning of environmental stress and/or change. Monitoring population dynamics of sensitive species may act as an indicator of general population health and as early warning of environmental change. Some parameters of interest include settlement and recruitment, growth, reproduction and recruitment.

Settlement and recruitment are distinct processes that are often synonymized and confused. Settlement is the process by which the usually microscopic early life stages of an organism (larvae, spores) transition from a planktonic phase(s) in the water column to a benthic or near-benthic (demersal, in the case of fishes) phase(s) on or near the reef or other sea floor substratum. If the settled organism survives and grows past metamorphosis it becomes a juvenile, which, after further growth may become large enough to be identified and counted with members of its cohort as a recruit. With subsequent growth, development and survival this recruitment cohort may result in a population of reproductive adults.

Growth is the process by which an organism adds biomass. Animals are assumed to grow at a higher rate in advantageous environments and growth rates have often been used as indicators of a healthy environment.

Reproduction is the process by which populations of organisms produce new or replacement organisms. Reproduction may occur either sexually or asexually in many marine organisms; indeed many organisms such as corals often have multiple reproductive modes. Most sexual reproduction produces planktonic larvae that spend a species-specific range of time adrift in the water. Organisms that reproduce sexually may do so just once and then die, or reproduce multiple times before dying. These reproductive strategies are termed semelparous and iteroparous, respectively and are important with respect to the need to apply the most appropriate resource management approaches based on species reproductive modes. In many coral reef organisms, including many corals, asexual reproduction may occur by budding, fragmentation or other means. Asexually produced offspring are genetically identical to their parent organism.

Survival is the process by which organisms may proceed through successive life stages to become reproductive adults. Once all breeding has been completed (or in some case cannot occur successfully because of environmental conditions), adult survival is no longer relevant except to maintain individuals as “placeholders” in the environment until new individuals can successfully recruit and replace adults. The importance of senescent individuals to an ecosystem varies from species to species. There are many invertebrate marine species that might be of interest for PACN parks to monitor population dynamic parameters of focal species or species of interest. Included among these are species that are harvested and whose population dynamics could be studied concurrently with other fisheries related investigations (e.g. endemic limpets [opihi], polychaete worms [pololo]). Coral population dynamics are another focal invertebrate population dynamic ecological attribute that would be of interest to monitor by PACN parks, and of particular importance to coral species are recruitment rates.

Focal marine fish population dynamics

Changes in population parameters of some species, such as butterfly fish or damselfish, may serve as early warning indicators of environmental stress or change. Many of these focal species also may be of interest to parks if they are a targeted fisheries species. Another example of a species of (both biological and cultural) interest are the sharks at PUHE on the Island of Hawaii.

Focal plant and algae population dynamics

Marine primary producers are important species and are sensitive to environmental change (both natural and anthropogenic) and can act as indicators of specific change. Ample scientific evidence shows phase shifts from coral to algal dominated communities are associated with specific measurable environmental perturbations (e.g. eutrophication, overfishing). Monitoring the growth, distribution, and reproductive dynamics of more sensitive algae or plant species provides information that may act as an early warning for a marine community.

Focal T&E population dynamics

Threatened and endangered species are an important component of biodiversity. A better understanding of population trends are needed for protected species. Parks are mandated to monitor their condition and implement conservation activities to further their recovery (Endangered Species Act and Marine Mammal Protection Act).

Invasive population dynamics

Marine invasive species are a potential concern for many PACN parks. In Hawaii 21% of marine invasive species originate from the Indo-Pacific region (Eldredge and Carlton 2002). The large geographical extent of the PACN result in some species native to one region, are invasive in another. For example, the alga *Acanthophora spicifera* was accidentally introduced by the hull of a vessel to Hawaii from Guam (where it is native) in the1950s. The most common introduction mechanism in the Hawaiian Islands have been via hull fouling, solid ballast, ballast water, and intentional fishery release (Eldredge and Carlton 2002, Godwin 2003).

Disease

The presence and persistence of disease in a population is a gauge of a population's health. Disease occurrence can be the result of other physiological stresses acting (e.g. change in water temperature) on an organism within the aqueous environment. Disease may also directly kill or weaken organisms impairing their ability to survive other stressors. Presence of disease interferes with reproduction, growth and other organismal functions. Disease easily spreads in an aqueous environment and could have severe and widespread consequences, with community-level effects (e.g. phase shift). Disease can be spread by the movement of water or could be spread by coallivorous fish (e.g., bacterial infections on corals). Occurrence and tissue samples from larger invertebrates or fish might provide some clue of disease type; it is more difficult to observe in coral reefs as tissue loss from disease is similar in appearance to damage from predation (i.e. requiring predator exclusion in any monitoring program for disease of corals).

Marine water quality

Water quality is an important measure of ecological health for marine ecosystems. Degraded water quality affects the health and distribution of marine plant and animal species. This subject is discussed in detail in the water quality conceptual model (in the water quality workgroup overview, another appendix to the PACN Monitoring Plan).

ECOLOGICAL EFFECTS

Working hypotheses of the links between environmental stressors and ecological attributes. Rated as: low, moderate or high for a level of certainty in the PACN. Areas where more research might be needed are indicated with a level of certainty as "unsure." The pathways are briefly described and are represented by the yellow diamonds in Figure 1.

Benthic landscape

Relationship of benthic landscape to extreme weather events.

Extreme weather events (such as tropical cyclones) reduce the three dimensional structure (rugosity) of reefs by breaking branching and other "delicate" corals (Rogers 1993, Dollar and Tribble 1993). Rugosity is strongly correlated with density of individuals and species diversity on coral reefs. Reducing rugosity has been shown to lower fish diversity on coral reefs (Jokiel et al. 2004, Friedlander et al. 2003). Extreme weather can also remove and decimate seagrass beds (including subsurface damage), shift softbottoms, and increase mortality in intertidal areas.

Level of Certainty – Medium/high

Relationship of benthic landscape to recreational activity (anchor damage, reef trampling, etc.)

Recreational activity has a deleterious impact on the benthic landscape. With over 6 million visitors participating in marine-related activities in Hawaii alone, this effect could have some consequences at the landscape level, particularly with high use areas also frequented by locals alike.

Not only does entanglement directly affect marine mammals and sea turtles, but it also affects coral reefs and colonies. In a popular fishing spot on Oahu, Hawaii, Yoshikawa and Asoh (2004) found that 65% of coral colonies had fishing line entangled on them and 80% of the colonies were dying or dead. These large scale patterns of coral death could contribute to large-scale changes in the community, particularly in areas where invasive species might be more likely to occur.

Impact from increased recreational use near coral reefs is a concern in many MPAs around the world (Jameson et al 1999, Tratalos and Austin 2001, Tabata 1992, Rouphael and Inglis 2001, Zakai and Chadwick-Furman 2002, Barker and Roberts in press). Increased coral breakage is associated with popular snorkeling and dive locations as well as increased coral damage with increased dive time. In the Red Sea Riegl and Velimirov (1991) found that areas where large patches of corals were dead had been replaced by macroalgae communities.

Intertidal landscapes

Relationship of intertidal landscape patterns to alteration of coastal habitats

Anthropogenic changes to the coastal area have direct effects on the intertidal region at the landscape level. Installation of jetty, piers, groins, and other coastal reinforcements can alter the character of the intertidal area and its associated communities. For example, installation of a jetty will cause a downstream loss of soft sediments, potentially exposing hard substrate to colonization.

Level of Certainty – Medium/high

Relationship of intertidal landscape patterns to invasive species

Invasive species can out compete native species by monopolizing space, excreting toxic compounds, or directly interacting (i.e. predation) with native species. Intertidal invasive species are poorly studied in the Pacific, with few documented alien species and little known about their ecology. In a recent study in a rocky intertidal zone of Oahu, Hawaii, Baumgartner and Zabin (2004) found that 10% of marine invertebrates and 11% of marine algae were composed of non-native or cryptogenic species. They worry that intertidal communities could be altered when invaded by invasive species, particularly if there is little predation occurring here. Alteration in intertidal communities could have a larger effect on the landscape level.

Level of Certainty – Unsure

Invertebrate Community Dynamics and Structure

Relationship of invertebrate community dynamics to spread of invasive species

The identity and ecological effect of marine invasive species is poorly known, but is the focus of considerable research effort (e.g., Bishop Museum, University of Hawaii Botany, CSIRO COTS surveys). A few cases in Hawaii illustrate the considerable ecological and economic impacts of marine invasives (DAR 2003, Smith et al. 2002, Smith et al. 2004). Invasive algae can come to dominate reefs, either growing in areas where coral were decimated or as a result of nutrient loading, overgrowing and eventually outcompeting corals. Either case, algae can ultimately cause a phase shift in the community structure. In some areas of Hawaii, invasive algae such as *Kappaphychus*, *Acanthophora* and *Gracilaria* have overgrown and killed coral, altering the invertebrate community. While similar cases are certain to exist in other areas of the Pacific, at present they are poorly documented (e.g., Guam, Draft Guam State of Reef 2004). Another invasive species, native to the Pacific Islands, the Crown of thorns seastar (*Acanthaster planci* or known as COTS) have been shown to alter community composition (Birkeland 1989). The loss of coral by predation facilitated replacement by macro-algae and an increase in herbivorous fish with a decline in corallivorous fish.

Level of Certainty -- Low

Relationship of invertebrate community dynamics to changes in water temperature and UV radiation.

Invertebrate communities, particularly coral reefs, are dependent upon light to survive and can be intolerant to even small temperature changes. A prolonged exposure to an increase in temperature leads to decreased photosynthetic rates and protein denaturing leading to bleaching (Porter et al. 1999). Large scale coral bleaching has been correlated with elevated water temperature (Berkelmans & Oliver 1999, Brown 1997, Glynn 1993, Jokiel and Coles 1990). Biological response of corals to bleaching result in both increased mortality and decreased fecundity with potential effects of changing community structure (Hoegh-Guldberg 1999).

In the PACN, one of the greatest threats identified for NPSA is increased coral mortality due, in part to bleaching and increased sea surface temperatures (Craig and Basch 2001). Bleaching events have recently been observed to coincide with increased sea surface temperatures in the Northwestern Hawaiian Islands (Aeby et al. 2003).

These bleaching events may also be influenced by ultraviolet (UV) radiation. Many invertebrates, including corals, are sensitive to high levels of UV radiation, which can cause bleaching and mortality in corals (Lesser et al. 1990, Gleason and Wellington 1995). Invertebrate community structure is also partially determined or controlled by UV radiation as corals show mass mortality for some UV wavelengths (Jokiel 1980).

Level of Certainty -- High

Relationship of invertebrate community dynamics to eutrophication.

In general, algae are better able to exploit increases in water nutrients, increasing their growth and reproduction and their ability to compete with corals for space on the benthos (McCook et al. 2001, Smith et al. 2004). Algae, in the presence of high nutrients, often come to dominate the benthos by killing, excluding and reducing coral abundance and diversity (Smith et al. 1981). This change in species dominance causes a cascade of ecological change through the invertebrate community, that is, a phase shift (Smith et al. 1981).

Level of Certainty -- High

Relationship of invertebrate community dynamics to pollutants and toxins.

Coral and other invertebrate larvae have been shown to be highly susceptible to waterborne pollutants, often suffering mortality at concentrations lower than those set for human health and safety by the EPA. Interruption of recruitment leads to long-term instability and can lead to phase shifts. Many invertebrates experience sub-lethal effects from pollutants. These effects can range from the inhibition of reproduction, reduction is fecundity, and lower growth rates. Some contaminants bioaccumlate in the food web and can be become significant human health concerns.

Level of Certainty -- Medium/high

Relationship of invertebrate community dynamics to sedimentation.

Many invertebrates, including coral, are sedentary in their adult form and many species are poorly adapted to remove sediments. Increases in sedimentation rates above natural background levels can lead to significant invertebrate mortality. Sediments also inhibit coral larval recruitment, and can lead to long-term phase shifts in coral reef ecosystems.

Level of Certainty -- High

Relationship of invertebrate community dynamics to extreme weather events.

Invertebrate communities are susceptible to extreme weather events. Corals are structurally fragile organisms and high ocean surf will crush delicate species. Surf also affects sea grass beds and soft bottom invertebrate communities by changing sediment characteristics and retention times. The frequency, magnitude, and timing of extreme weather events have well documented effects on coral reefs and the associated communities (e.g. Rogers 1993).

Level of Certainty -- High

Relationship of invertebrate community dynamics to incidence of disease.

Disease, including bleaching in corals can lead to invertebrate mortality. This occurrence has been well documented in corals and Caribbean sea urchins. Changes in the population levels of these keystone species can create phase shifts in the coral reefs and associated communities, leading to shifts in the diversity and abundance of invertebrate communities.

Level of Certainty -- High

Relationship of invertebrate community dynamics to fisheries harvest.

Fish assemblages are important components of coral reef and associated communities, often occupying a keystone role. While individual species seldom exert strong influence over coral reef community dynamics, fish guilds have a profound effect on maintaining community structure. Ample data exists documenting coral reef phase shifts linked to overharvest of herbivorous fishes (e.g., McManus et al. 2002).

Level of Certainty -- High

Relationship of invertebrate community dynamics to recreational activity (anchor damage, reef trampling, etc.)

Depending on severity, mechanical damage (either directly to the organism or an associated abiotic substrate/structure) can injure or kill organisms, reduce their ability to compete, or increase their susceptibility to disease or other mortality sources. Mechanical damage can have cascading ecological effects through a community when abiotic (e.g. cobbles, boulders, overhangs) or biotic (e.g. coral reef, macroalgae) structures that serve as important microhabitat are moved or destroyed. Mechanical damage to corals (as measured by decrease in live coral coverage) has been documented as a result of destructive fishing methods (McManus et al. 1997), at diving sites (Jameson et al. 1999) and popular snorkeling areas (e.g. Hanauma Bay, Oahu).

Level of certainty – High

Fish assemblages

Relationship of fish assemblage to fisheries harvest.

Removal of species from the assemblage will alter the composition and dynamics of the assemblage. For example, predator removal can lead to increases in herbivorous species that could affect primary producers, abundance of other herbivores and community structure. Two globally acknowledged concepts, 'fishing down the food web (Pauly et al. 1998)' and 'ghost communities (Dayton et al. 1998, Tegner and Dayton 2000)' both are directly related to fish assemblages. They are covered in detail in the introduction of this report. Essentially, they describe our perceptions of community structure and dynamics and how harvest and human induced changes can affect our perceptions.

In Hawaii, Friedlander and De Martini (2002) compared fish assemblages in the Main Hawaiian Islands (MHI) to those in the Northwestern Hawaiian Islands (NWHI) and found considerable differences. Apex predators (sharks and jacks) in the NWHI consist of more than 54% of the total fish biomass; whereas in the MHI they consist of less than 3% of the total fish biomass. These results are an example of 'fishing down the food web,' and the effect of high fishing pressure on fish assemblages. If management action is not undertaken, removal of fish may follow the globally observed pattern whereby the next trophic level may be targeted after the highly prized larger fish are removed (Pauly et al. 1998).

Level of Certainty -- High

Relationship of fish assemblage to spread of invasive species.

Introduction of invasive species can increase competition for resources such as food or space. Invasive species may also disrupt the trophic web of a fish assemblage; predatory non-native fish can consume native species. Non-fish alien species may provide an alternate food source or may compete with and or displace preferred foods of some native species.

Level of Certainty – Low

Relationship of fish assemblage to pollutant and toxins.

Pollutant effects on fish assemblages are, at present are poorly understood. Many pollutants (e.g. PCBs, mercury, pesticides, etc.) bioaccumlate up the food web, reaching high concentrations in top level predatory fish. The effects of these pollutants on long-term health, survival and reproduction of these species is unknown and it is difficult to predict affects of these contaminants on fish assemblages.

Level of Certainty – Low

Algae and Vascular Plant Community Dynamics

Relationship of algae and marine plant community dynamics to Eutrophication

Nutrients are essential to life and usually considered to be limiting to many biological processes, including growth and reproduction. In the marine environment, nitrogen is usually considered to be limiting, however considerable debate exists. Some species are capable of exploiting nutrient increases; however, elevated nutrient levels may inhibit growth, reproduction, or survival. Nutrient loading into the marine environment results in favorable conditions that facilitate an increase in phytoplankton and macroalgae that can compete with coral for space (Done 1992). For example, in Kaneohe Bay, nutrient-rich sewage discharge facilitated the growth and subsequent take over of the coral community be the macroalga *Dictyosphaeria cavernose* (Jokiel et al. 1993, Smith et al. 1981). Proliferating algae in nutrient rich waters has also been found to outcompete and contribute to seagrass declines (McGlathery 2001).

Level of certainty – High

Relationship of algae and marine plant community dynamics to sedimentation

Sedimentation reduces light availability for photosynthesis for corals and seagrasses. This reduced light availability decreases the photosynthetic rate of the zooxanthellae resulting in less energy for the coral host. Large amounts of fine sediment can have similar smothering effects on algae and seagrasses resulting with large die-offs (Kirkman 1990).

Sedimentation may also have indirect effects that benefit macroalgae. Sedimentation can be associated with terrestrial run-off that also has high levels of nutrients. Nutrients may have more of a negative effect on coral reefs than macroalgae, thus providing an opportunity for the algae to expand after the coral's demise. Large macroalgae have also been found to act as a sediment trap, and might add to pronounce these effects (Smith et al. 2001).

Level of Certainty – High

Relationship of algae and marine plant community dynamics to incidence of disease

Occurrence of disease (e.g. wasting disease) in seagrass species can cause large-scale die-offs (Den Hartog 1996). Large-scale die-offs may have an impact on community dynamics and structure, based on the role of seagrass in the marine ecosystem. Impacts may be direct, impacting species such as the green sea turtle that include seagrass as part of their diet (Russell and Balazs 2000). Indirect impacts may be reflected by adjacent coral reefs communities, such as fish that use seagrass beds as nurseries.

Level of Certainty – Low/Medium

Coralline lethal orange disease (CLOD) is a lethal disease affecting coralline algae in the IndoPacific. A bacterial pathogen, it spreads across a coralline algal thallus leaving behind bare skeletal carbonate remains; and once it reaches the end of the algal thallus, it forms filaments that disperse with water movement (Littler and Littler 1995). Coralline algae are important to reef-building corals, helping to cement sand and dead coral to create stable substrate. Coralline algae may play a role in facilitation of chemical cues for settling invertebrate recruits. In their absence accretion may not occur and fleshy macroalgae may overgrow in their once occupied space, inhibiting reef-building coral recruits.

Level of Certainty – Low-Medium

Relationship of algae and marine plant community dynamics to extreme weather events

Storms and tsunamis can cause structural damage to mangroves, seagrass beds and macroalgae canopy. The intensity and frequency of storm occurrence can influence recovery rates. For example, in a northern Australian bay, 70% of seagrass beds were depleted as a result of one cyclone activity and took 10 years to recover. Whereas in another area after significant damage after a cyclone, undamaged subsurface seagrass structures allowed recovery of their abundance to pre-cyclone levels only 6 months later (Kirkman 1997). Additionally, after heavy weather (i.e. tropical cyclones) a decrease in coral can occur simultaneous to an algal increase, and phase shift the community towards an algal dominated one (Rogers et al. 1997, Connell et al. 1997).

Level of Certainty – Medium-high

Relationship of algae and marine plant community dynamics to spread of invasive species

The introduction of invasive species can impact and change community structure and dynamics with perturbations felt throughout the ecosystem (Smith et al. 2002, Smith et al. 2004). There are many endemic species in the PACN adapted to specific conditions. Invasive species have the potential to invade and out-compete these species. For example, in Hawaii, the effect of the invasive green alga *Avrainvillea amadelpha* on the endemic seagrass *Halophila hawaiiana* is a potential threat as it appears to displace the native seagrass on the southern shores of Oahu in Hawaii (K. Peyton, pers comm.). This displacement could be of importance since *H. hawaiiana* has been found in the endangered green sea turtle's (*Chelonia mydas*) diet (Russell 2000). Another invasive alga, *Gracilaria salicornia*, was intentionally introduced for experimental aquaculture to Oahu. In areas of Waikiki that once were home to over 60 different algal species, now only contain *G. salicornia* (Smith et al. 2004). The increased biomass of invasive algae can lead to physical changes (e.g. coral cover) with decreases in biodiversity and community dynamics (Done 1992, Rodgers and Cox 1999, Smith et al. 2002).

Level of Certainty – High

Relationship of algae and marine plant community dynamics to pollutants and toxins

Algae and plants can act as pathways for pollutants and toxins to enter the marine food web. Soluble pollutants and toxins are incorporated into plant and algae tissues and consumed, potentially influencing higher trophic levels such as piscivorous fish, marine mammals, and people. Some of these toxins produced by algae include paralytic shell fish poisoning (PSP) and ciguatera. Paralytic shellfish poisoning is caused by dinoflagellates that bloom as a result of increased nutrient loads, they are absorbed by feeding shellfish (e.g. clams), remain in their tissue and are consumed by people. Degraded water quality, resulting from an increase in temperature and/or combined with terrestrial runoff might be a factor in some of the blooms associated with red tide events that could cause occurrence of PSP.

Level of Certainty – Low-medium

Intertidal community dynamics

Relationship of intertidal community dynamics with spread of invasive species

The Caribbean barnacle (*Chthamalus proteus*) was introduced to Hawaii between the mid 1970s and 1990s and has become the most abundant organism in the high intertidal region (Coles and Eldgredge 2002). It does not appear to have displaced native species, however. In some places it may compete with native limpet (*Cellana)* species (Coles and Eldgredge 2002) and with another non-native barnacle (DAR Invasive Species Report).

Level of Certainty – Low-medium

Relationship of intertidal community dynamics with alteration of coastal habitat

The distribution of intertidal organisms is strongly correlated with substrate type. Many plants and animals are restricted to hard substrate or sandy bottoms, or even limestone as opposed to basalt. Large scale changes in the intertidal landscape, particular in the type or composition of substrate, can cause extensive changes in the species composition of the intertidal community

Level of Certainty –High

ECOLOGICAL MEASURES

Benthic landscape

Distribution, relative abundance, cover by type, rugosity.

Intertidal landscape pattern

Distribution of biological flora/fauna by physical surroundings

Marine recreational use

Visitor density (including dive hours), measure of damage (e.g. distribution & amount of severity of anchor damage, amount of lead sinkers, fishing line or net entangled on bottom, number of broken corals level/degree of trampling, water films)

Fisheries harvest

CPUE (control & harvested population), collection statistics (quantity, age/size), composition

Invertebrate community structure and dynamics

Species composition & counts, percent cover of species, diversity, density/abundance, rugosity, coral growth rates

Intertidal community structure and dynamics

Abundance and trends of selected assemblages or groups, evenness, richness, distribution, assemblages of foundation species

Fish assemblages

Relative abundance, demographics, diversity

Algae and vascular plant community structure and dynamics

Distribution, species composition & diversity, density, biomass, shoot density (seagrass)

Focal algae and vascular plant population dynamics

Frequency for solitary algae, cover by species, demographics, recruitment, reproduction, growth rates. Qualitative data including general health.

Focal marine fish population dynamics

Abundance, distribution, demography (size/age class frequency), qualitative data including general health and color morph

Focal invertebrate population dynamics

frequency/density (number per unit area), distribution, growth rates, survival, recruitment rate, reproductive index. Qualitative data, including general health

Focal T&E population dynamics

Abundance, demography (where appropriate), distribution, recruitment, growth, survival. Prevalence of disease, pathogens, other population threats. Qualitative data including general health

Focal invasive species population dynamics

Presence/absence, trends in abundance, distribution and density, demography?, lab taxonomy?

Disease

Disease or threat prevalence, level, or presence/ absence; distribution and numbers of host and/or vector species involved; abundance or density of affected population. Stage of disease/infestation, host condition. Potential causes: presence/absence; distribution, ID, and numbers of host and/or vector spp.

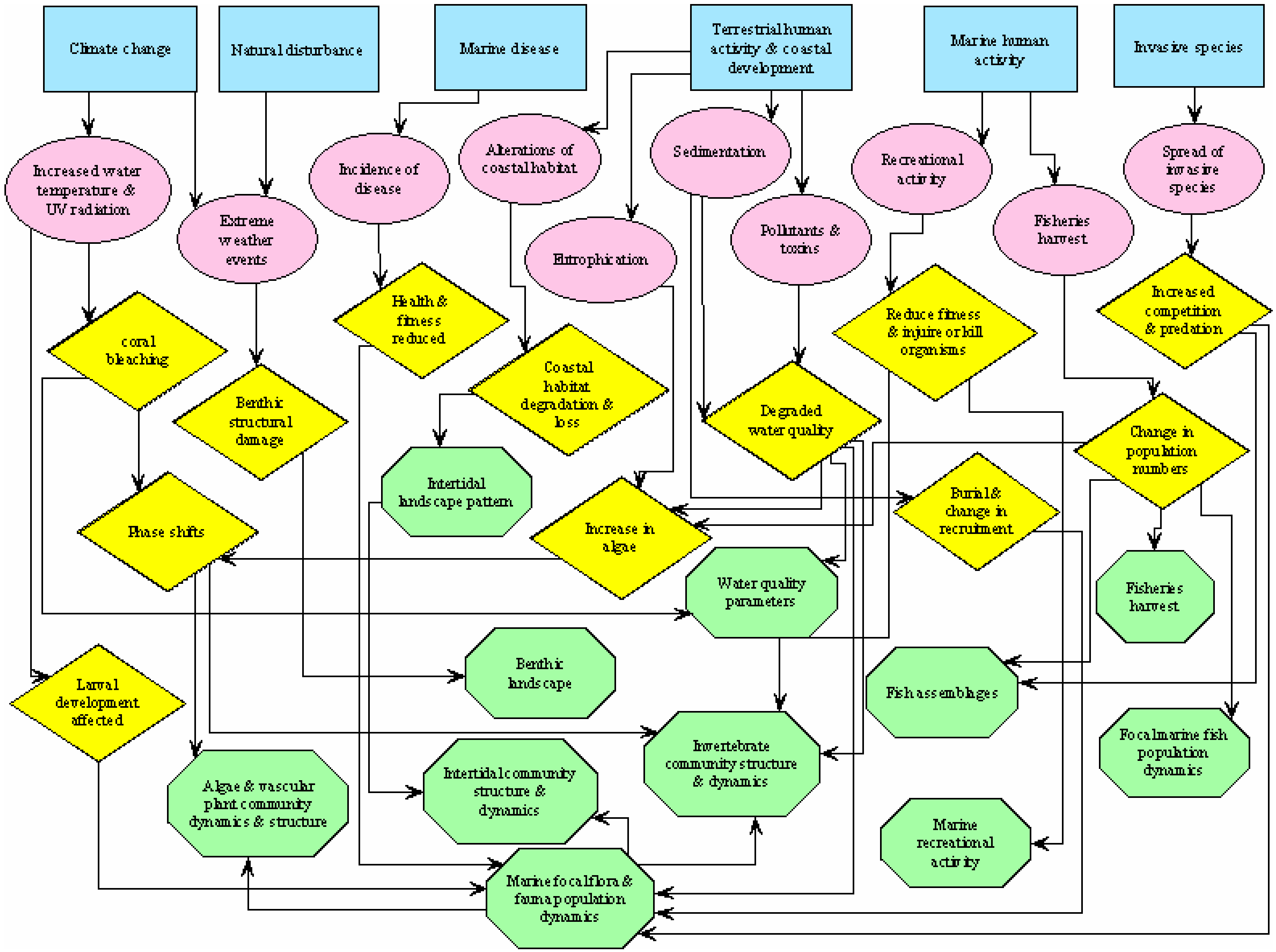

Figure 1. PACN marine conceptual model as described in preceding text.

PARK AND NETWORK-WIDE ISSUES

Parks across the Pacific may vary considerably in environmental and social climate, but ultimately they have much in common including both major natural resources and natural resource issues.

Major marine habitats found in the PACN parks include communities comprised of coral reefs, seagrass, algae, soft bottom, mangroves, and intertidal zone. This section will describe these major habitats, and then provide more detail on individual resources found within the parks, including those that were not included in the conceptual model.

Local and park issues can be placed into a dozen broad categories. A thirteenth category (bioprospecting) has been added because of its potential to be a significant issue at some Pacific Island parks in the future. Following the presentation of these broadly categorized issues, stressors affecting each park will be highlighted in more detail. Most marine threats are terrestrial derived and are a product of human activity and while specifics of management challenges and scientific understanding may vary, generalizations can be made for nearly all Pacific Island Parks.

MARINE HABITATS FOUND IN PACN REGIONS

Coral Reefs

Mariana Islands: Because of their proximity to the west Indo-Pacific, reefs in the Mariana Islands are diverse, well-formed, and moderately well studied. In the Mariana Islands there are 119 known species of non-scleractinian corals (Paulay et al. 2003), 377 species of scleractinian corals (Randall 2003), 26 species of hydrozoan coral (Randall 2003) and 1019 shorefish species (Myers and Donaldson 2003). Reefs within WAPA are predominately fringing with wide shallow reef flats. Proximity to large population centers and easy access have made them popular sites for fishing and recreation. The reefs at AMME lie within the Managaha Lagoon, the only true lagoonal system within the Mariana Islands. This lagoon is enclosed by an extensive, well-developed barrier reef system and is the location of Saipan's principal harbor and the focus of its ocean-based tourism.

American Samoa: American Samoa has extensive well-formed reefs with over 250 species of coral and 900 species of fish. All of the reefs are fringing in nature and drop quickly into very deep water (thousands of meters). Most fore-reef areas have well developed spur and groove formations. At Tau Island, large coral bommies (*Porites* sp.) are among the largest living coral colonies in the world.

Hawaii: Because of the geographic isolation of the Hawaiian Islands, they have the lowest coral reef species diversity relative to American Samoa, Guam and Saipan. Conversely, they are also the most studied. Although diversity might be relatively low compared to other areas in the PACN, Hawaii has a high rate of endemism - 20% for reef building corals. Reefs off the Hawaiian parks are primarily fringing reefs or coral colonized volcanic rock. The main islands are home to approximately 65 coral species, 500 fish species, 600 species of algae and a large but unknown number of (non-coral) invertebrates.

Parks along the West coast of the Island of Hawaii have moderate reef development. Coral environments on exposed shores such as at HAVO on the south coast of Hawaii, and HALE on the eastern coast of Maui and KALA on the north shore of Molokai are not coral reefs per se, but are primarily bare volcanic or basalt pavement or boulders with some isolated wave-resistant coral heads. Active volcanism and large oceanic swells have precluded the formation of substantial reef structure at HAVO on much of the southern coast of the island of Hawaii.

Seagrass

Mariana Islands: Currently, nine species are known in the Mariana Islands (Lobban and Tsuda 2003), with Guam having three species, *Enhalus acoroides*, *Halodule univervis*, and *Halophila minor* (Eldgredge 1979, Tsuda et al. 1977, Lobban and Tsuda 2003). Guam and Saipan have extensive nearshore sea grass meadows. Within the WAPA, *Enhalus acaroids*, a large clump-forming plant that inhabits shallow sand flats is common, but all three Guam species are represented.

American Samoa: Because of an apparent lack of suitable habitat, seagrasses are a relatively minor component on Samoan reefs. Two or three species are present in the territory.

Hawaii: Hawaii has two seagrass species within its waters and neither forms extensive seagrass beds. *Halophila hawaiiana* is endemic to the islands and its short height often makes it cryptic and difficult to find (Phillips and Menez 1988). It also serves as a food source for the Hawaiian green sea turtle, (*Chelonia mydas,* locally known as Honu) (Russell and Balazs 2000). The seagrass, *Halophila decipiens* is a recent introduction to the Hawaiian Islands, first observed in the late 1990s. This species is almost identical in appearance to the endemic species. The status of this invasive species is not entirely clear at this time, however, the alien seagrass has been found in the diet of the green sea turtle (Russell et al. 2003).

Algae

Mariana Islands: The Mariana Islands harbor a diverse array of marine algae. Six hundred and twenty-five species were attributed to the Mariana Islands in a recent review of algal diversity (Paulay 2003). Guam has 229 species of benthic macroalgae, with 22 Cyanophyta (blue-green algae), 109 Rhodophyta (red algae), 28 Phaeophyta (brown algae) and 70 Chlorophyta (green algae (Lobbon and Tsuda 2003). The University of Guam is in the process of placing photographs of these species online (http://www.uog.edu/classes/botany/474/).

American Samoa: American Samoa has a diverse algal flora that has only recently begun to be characterized systematically. Because of taxonomic difficulties with many groups, algae diversity in Samoa is not well known. Small algal turfs and crustose coralline species seem most apparent on many reefs. Macroalgae do not appear to be common on some reefs; where macrophytes occur they are often in crevices in the reef. Crustose corallines are an important component on Samoan reefs, cementing reefs and providing settlement substrates for corals and other invertebrates. In the Samoan Archipelago 318 species are documented with 262 of these known to occur in American Samoa (Skelton 2003).

Hawaii: The marine algae of the Hawaiian Islands have recently been very well characterized. The Hawaii Biological Survey (http://hbs.bishopmuseum.org/) estimates 636 known species of marine algae (including 58 species of marine Cyanobacteria) in Hawaiian waters (Eldredge and

Evenhuis 2003). Of the algae, 80 are endemic and 19 are non-indigenous species. Algae occur from the intertidal zone, across all shallow reef environments, some soft sediment habitats, and sometimes to reefs and adjacent environments at great depths, but are prevalent particularly in shallower benthic habitats. Some marine alien or invasive algae threaten coral reefs in the Main Hawaiian Islands and constitute a serious management issue. The Hawaii Coral Reef Initiative supported the 'Ecological Success of Alien and Invasive Algae in Hawaii' project that identified four species in particular that pose a threat to Hawaii's coral reefs: *Acanthophora spicifera*; *Gracilaria salicornia*; *Hypnea musciformis*; and *Kappaphycus* species (Smith et al. 2002).

Soft Bottom

Mariana Islands: Currently little is known about the soft bottom communities at WAPA or AMME. Extensive sand plains exist at 25-30 meters depth. Sand patches are also present on reef flats in <1 meter of water.

American Samoa: Extensive areas of soft bottom are generally absent in the shallow waters of American Samoa. Much of the reef drops steeply into deep water and is therefore not conducive to collecting sand. Small sand patches are present, particularly in reef flat, lagoon and spur and groove areas, and sand is also present in some deeper water areas.

Hawaii: Hawaiian soft bottom ecosystems have received considerable scientific study and in a few localities are well inventoried and characterized. Soft bottom communities in some areas are examined to determine impacts from sewage discharge. These environments contain an extremely speciose community of soft-bodied animals (e.g., polychaetes and other worm-like animals), as well as crustaceans and molluscs. Certain fish species (e.g., gobies, flounder, cretids) are found on soft bottoms.

Mangroves

Mariana Islands: At least eight mangrove species occur in Guam; however WAPA presently has no mangroves within park boundaries. The park appears to lack suitable habitat for mangroves to become established. Saipan has only a single species of mangrove (*Brugeria* sp.), and nearly its entire distributional range on the island occurs within the park boundary. AMME has extensive mangrove areas along part of the shore and in a 33-acre inland wetland, the only wetland of its type in the Mariana Islands. The AMME mangrove wetland has approximately 200 species of plants and animals, including two endangered species of birds.

American Samoa: American Samoa is on the periphery of the distributional range of mangroves in the Pacific and they are found only on Tutuila and Aunuu and include oriental mangrove (*Bruguiera gymnorrhiza)*, red mangrove (*Rhizophora mangle)* and cedar mangrove (*Xylocarpus moluccensis)* (Bardi and Mann Technical Report 45). Mangroves in Samoa are generally small and have a restricted distribution, apparently because of a lack of suitable habitat. Most mangroves have been removed by people, with an estimated 30% loss from 1992 to 2003 (Bardi and Mann Technical Report 45). Mangroves with seawater exchange occur at the mouth of Faatafe Stream just outside the park at Vatia in the southeast corner of Vatia Bay (Biosystems Analysis 1992). The mangrove swamp inside the park between Polauta and Siuono Ridges is predominantly a freshwater marsh.

Hawaii: Hawaii has no native mangrove species, but seven different species (including one variant) have been introduced between 1902 and 1960 (Allen 1998). Red mangrove (*Rhizophora mangle)*, oriental mangrove (*Bruguiera gynmnorrhiza)* and *Conocarpus erectus* have all become established with self-maintained populations. Efforts to control or remove these trees have been undertaken because the presence of mangroves alters the shoreline and negatively influences the coastal environment including anchialine pools, fishponds and archaeological sites (Allen 1998). Negative effects have been observed in decreased habitat for shore birds and water birds including the endangered Hawaiian stilt (*Himantopus mexicanus knudseni*). Relatively small numbers of mangrove trees occur at KAHO and KALA.

Intertidal

Mariana Islands: Guam has a mixture of hard- and soft-bottom intertidal areas, both of which can be found within WAPA. The intertidal region of AMME is entirely soft-bottom, forming an extensive sand beach that is heavily used for recreation, except near the marina where the shoreline has been reinforced with cement walls.

American Samoa: American Samoa has extensive stretches of exposed rocky intertidal intermixed with white sand beaches. Some beaches are currently used for nesting by threatened or endangered sea turtles.

Hawaii: Hawaii has a mixture of hard- and soft-bottom intertidal areas. In the Hawaiian National Parks, hard-bottom intertidal areas consist of primarily basalt rock. Soft bottom areas range from primarily calcium carbonate (white sand) to almost entirely basaltic sands (black sand beaches). Other minerals may collect locally in beach sediments, producing on occasion other beach types (e.g. green sand beaches with a high content of the mineral olivine).

Hawaiian intertidal communities have relatively low diversity compared to other regions of the Pacific. Communities on hard-bottom intertidal areas vary in species composition depending on substrate type, for example, endemic limpets (of the family *Patellidae* and locally called opihi) are found exclusively on basalt substrate. There are three species of endemic limpets found in the main Hawaiian Islands intertidal regions (a fourth is found in the Northwestern Hawaiian Islands) and include: black-foot limpets (*Cellana exarata* or locally known as opihi makaiuli), yellow-foot limpet (*Cellana sandwicensis*, or opihi alinalina), and giant opihi (*Cellana talcosa* or opihi koele).

EXISTING NATURAL RESOURCES FOUND WITHIN INDIVIDUAL PACN PARKS

WAPA

The legislated boundary of WAPA extends into the ocean and encompasses approximately 1000 acres of submerged land. The following list is alphabetically arranged.

- Algae: Little is known about marine algae within the park. Extensive algal reefs are not believed to be in the park.
- Coral Reef: WAPA has extensive coral reef resources. Fringing reefs extend as far as 100 meters offshore before dropping quickly to 25-30 m depths. Reef slopes are coral covered. Several ephemeral and permanent streams incise the reef flats and provide

varied microhabitats. Many of the species on the reef occur nowhere else in the National Park System and make this a unique natural resource.

- Marine Mammals: Spinner dolphins shelter in the waters of the Agat Unit during the day before moving offshore to feed at night. Dolphins attract numerous tourists and vessels to the park daily. However, vessels tend to ignore the minimum distances and non-harassment regulations detailed in the Marine Mammal Protection Act and have been observed by park staff "herding" dolphins into better viewing areas.
- Offshore Islets: WAPA has a series of offshore islets that are the last remaining land areas in Guam that are free of the invasive brown tree snake. These islets are a refuge for numerous sea birds and several endemic species of lizard.
- Seagrass: Extensive sea grass beds, comprised mostly of *Enhalus acoroides*, but containing all three species found in Guam, line the shores of the Agat Unit. These sea grass beds may serve as a nursery habitat for coral reef organisms. Other than at AMME, these sea grass beds occur no where else in the NPS.
- Threatened and Endangered Species - Turtles: Green (*Chelonia mydas*) and hawksbill sea turtles (*Eretmochelys imbricata)* have been observed in park waters, but no nesting has been recorded. Turtles are probably transient and may be feeding in extensive seagrass and algal beds, especially in the Agat Unit. hawksbill turtles have been observed by park staff feeding at depth in the Asan Unit.
- Soft Bottom: Little is known about the soft bottom communities in the Park. Extensive sand plains occur around 25-30 meters, and extended an undetermined distance seaward. Sediments occur in stream cuts that should harbor different species that at the base of the reef slope. Based on Guam's location in the Indo-Pacific, species found in this area are probably unique to the National Park System.

AMME

The legislated boundary of AMME does not extend past the high tide line and they have no submerged natural resources. Nonetheless, AMME has several significant marine resources.

- Beach: American Memorial beach (Microbeach) is one of the park's primary attractions for visitors. It has been the site of several turtle nesting attempts, the most recent of which occurred in 2001.
- Mangroves: AMME has the Mariana Islands' only wetland/mangrove system with the only mangrove species being the indigenous oriental mangrove, *Bruguiera gymnorrhiza*. This system is separated from the Managaha Lagoon yet appears to have a subterranean link(s) to the ocean. This wetland is home to federally endangered nightingale reed warblers (*Acrocephalus luscinia* or Gaga karisu in Chamorro) and houses many species of plants that are unique to the National Park System.
- Shore and Sea Birds: Several migratory birds have temporary residence within the park, including golden plovers (*Pluvialis dominica*, or dulili), Pacific reef-herons (*Egretta sacra*, or chuckuko atilong), red-footed boobies (*Sula sula rubripes*, or luao), and federally endangered Mariana common moorhens (*Gallinula chloropus guami*, or pulattat).

- Threatened and endangered species: Two sea turtle species, green (*Chelonia mydas*, haggan in Chamorro) and hawksbill (*Eretmochelys imbricate*, or haggan karai), have attempted nesting on AMME beaches in the recent past. It is believed that these attempts are “false nestings.” However, in the late 1990s large numbers of juvenile green turtles were found in the marina adjacent to the park boundary, suggesting that a successful nesting occurred nearby, potentially within the park.

NPSA

The legislated boundary at NPSA extends to either the 60’ depth contour or a quarter mile offshore, which ever is farther. Because of the steepness of the bottom, the park boundary extends a quarter mile offshore in all cases. Jurisdictional control requires clarification, because park lands, including submerged areas, are owned by the Territory of American Samoa and leased from the villages within the park.

- Algae: NPSA has large amounts of crustose coralline algae, which has been identified as a key component to reef formation. Numerous other algae species occur within the park. Fagasa Bay, however has a higher diversity of fleshy macroalgae (Skelton 2003).
- Beaches: There are sizeable stretches of carbonate sand beaches in all park units. Some beaches in all NPSA units are used for nesting by hawksbill sea turtles.
- Catadromous Fish: Catadromous gobies and other fish species occur in streams in hte Tutuila and Tau park units.
- Coral Reef: NPSA’s coral reefs represent the only southern hemisphere reef systems in the National Park System. These fringing reefs are in fairly good health and contain species that are probably unique within the NPS. The lagoon within the fringing reefs in the Ofu unit represents an unusual microhabitat with high species diversity. Fore-reefs have well developed spur and groove formations. The reefs in NPSA have about 200 species of coral and 900 species of fish. Several extremely large coral colonies (*Porites lobata*) grow in and around the Tau Island Unit of NPSA. These are believed to be among the largest coral colonies in the world, with many measuring over 10 meters in diameter.
- Intertidal: Much of the coastline within NPSA is basalt pavement, boulder and cobble. Many marine organisms that do not occur in other marine habitats make use of this area. There are also some low-relief carbonate benches. These hard substrates are interspersed with carbonate sand beaches.
- Marine Mammals: Endangered humpback whales (M*egaptera novaeangliae)*, locally known as tafola) have been sighted in the park. Spinner dolphins (*Stenella longirostris*) transit through the park and may be day resting. A pod of dolphins (species currently unidentified) day rests just outside of the park. Other marine mammals may be present, but data are unavailable.
- Offshore Islets: The Tutuila Unit has several offshore islets, including the impressive Pola (Cock’s Comb). Most of the islets are small, but serve as nesting sites for sea birds, including brown boobies (*Sula leucogaster*, or fuao) and brown noddies (*Anous stolidus*, or gogo).

- Sea Birds: Although seabird populations in the territory are not extensive, the park supports the largest colony of seabirds on Tutuila Island and an important colony of Tahiti petrels on Ta'u mountain. Sea bird species nest in the other park units with small colonies of brown and red-footed boobies and brown noddies on several of the islands. Black noddies (*Anous minutus*, gogo) and Tahiti petrels (*Pterodroma rostrata*, taio) nest on Tau Island
- Soft Bottom: The sandy substrate associated with coral reefs typically harbor species that do not occur in other reef environments.
- Threatened and Endangered Species - Turtles: Endangered hawksbill turtles (known locally as laumei uga) nest and feed within the park. Endangered green sea turtles (laumei enaena or fonu) occur in American Samoa and are presumably also in the park at times.

USAR

The legislated boundary of USAR does not extend past the high tide line, however the park has jurisdiction over two submerged vessels: the USS Arizona and the USS Utah. This jurisdiction does not extend to the surrounding submerged lands.

- USS Arizona: This is the primary resource in the park. While not a natural feature, the hull of the battleship serves as substrate for numerous organisms, including barnacles, oysters, algae, and corals. It also provides shelter for resting sea turtles.
- USS Utah: The park has administrative control over this vessel for research purposes. Similar to the USS Arizona, the hull of this ship serves as habitat for a wide diversity of encrusting organisms.
- Threatened and Endangered Species - Turtles: Green sea turtles (*Chlonia mydas*) are occasionally seen resting on the deck of the USS Arizona.
- Threatened and Endangered Species - Monk Seals: Monk seals (*Monachus shauislandi*) have been sighted rarely but with apparently increasing frequency in the last few years in the vicinity of the USS Arizona.

HALE

The legislated boundary of HALE does not extend below the mean high tide line and there are no submerged lands within the boundary. However, HALE has several significant marine resources on and immediately adjacent to the shoreline.

- Anadromous Fish: HALE streams are home to several species of Hawaiian stream gobies. These anadromous fish pass through the park's shoreline areas and offshore marine areas during part of their lifecycle.
- Intertidal: HALE has extensive intertidal basalt benches and numerous pebble beaches within its boundary. Most of the coast is exposed to rough ocean conditions. Endemic Hawaiian limpets (opihi) occur in the rocky intertidal, and are an important local fishery. A few tide pools are present, but they may be located just outside the park boundary. Tidepools are important nursery habitat for many reef species.

- Sea Birds: HALE has an assortment of sea birds that occur within the park. Hawaiian petrels (*Pterodroma sandwichensis*) nest on the steep cliffs of the volcano at elevations above 8000'; brown noddies (*Anous stolidus*, or locally known as noio koha) nest along the coast; and white-tailed tropic birds (*Phaethon lepturus*, koae kea) nest at mid-elevations. Band-rumped storm petrels (*Oceanodromo castro*) have been heard at elevations above 6,000' and great frigate birds (*Fregata minor*, iwa) are commonly seen flying.
- Threatened and Endangered Species - Monk Seals: Hawaiian Monk seals (*Monachus schauislandi*, Ilio-holo-i-ka-uaua), are endemic to the Hawaiian Islands and are federally listed as endangered. Monk seals have been observed resting on park beaches. In a recent survey by the National Marine Fisheries Services, monk seals were observed hauled out west of the park (Baker and Johanos 2004).
- Threatened and Endangered Species - Turtles: Green sea turtles, (*Chelonia mydas*, federally listed as threatened) have been observed in the waters adjacent to the park, and on occasion have been observed on park beaches. Nesting is believed to occur on park beaches, but data are not available.

KALA

The legislated boundary of KALA extends a quarter mile offshore and encompasses numerous marine resources. These are technically under the jurisdiction of the State of Hawaii.

- Algae: Very little is known about the marine algae within the park, but a new state record was recorded at Kukaiwaa. Recent surveys of Hawaiian marine algae have discovered several new species and range extensions. Since little marine work has been done to date at KALA, it is likely that rare, and perhaps new species, may be present in the park.
- Anadromous Fish: Four species of anadromous fish are found within the park. These gobid fish are Hawaiian endemics also found at HALE.
- Coral Reef: While some species of hermatypic corals occur at KALA, typical prevailing oceanographic conditions appear to prevent coral reef formation.
- Intertidal: The intertidal areas of KALA consist of exposed basalt benches, low and high cliffs, basalt boulder and cobble beaches, a black sand and a carbonate sand beach, and numerous tidepools. These tidepools may serve as nursery habitat for some coral reef-inhabiting species. Three species of endemic Hawaiian limpets (opihi), yellow and black-foot and a species generally restricted to the remote northwest islands (*Cellana melanstroma*), are found on the basalt bench, boulder and cliff areas (Minton and Carnevale 2004).
- Offshore Islets: There are three offshore islets within the KALA boundary. A number of sea bird species nest on all three islets. One islet has rats and two islets are predator free.
- Marine Mammals: Humpback whales (*Megaptera novaeangliae*) have been observed in park waters. Rough tooth dolphins (*Steno bredanensis*), spinner dolphins, and Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) are also known to transit through park waters. Bottlenose porpoise (*Tursiops gilli*) are also believed to be in the park.

Dolphins (known locally as *naia*), are often locally referred to as porpoises because the name dolphin is applied to fish such as mahi mahi.

- Soft Bottom: The park has a large subtidal sand patch off a black sand beach. The flora and fauna of this roughly 0.7 kilometer by 0.7 kilometer patch has not been adequately investigated.
- Threatened and Endangered Species – Monk seals: A small population of monk seals (*Monachus shauislandi*) is using beaches at KALA to pup. These endangered marine mammals are almost entirely absent from the main Hawaiian Islands, and the population at KALA is largest population outside of the Northwestern Hawaiian Islands.
- Threatened and Endangered Species - Turtles: Green sea turtles (*Chelonia mydas*, federally listed as threatened) occur in the park where they forage and nest when beach conditions are suitable. Seasonal deposition of sand can affect green turtle nesting. Hawksbill sea turtles (*Eretmochelys imbricate*) that nest on Maui have been satellite tracked to foraging grounds on the north coast of Molokai and may be occasional visitors to the park.

PUHE

The legislated boundary of PUHE extends into the water and encompasses Pelekanhe Bay. The park has a relatively small area of submerged land within its boundary. One third of the bay is covered in silt and coral rubble, another third by sand and basaltic pavement, and the final third by patch reefs surrounded by sand and silt (Cheney et al. 1977). The submerged land is technically under the jurisdiction of the State of Hawaii.

- Beach: PUHE has a single small sand beach that is an important visitor area. Historic coconut palms line the beach.
- Pond: A freshwater/marine pond is a primary resource within the park. Two gulches (Makeahuna and Pohaukole Gulches) drain into the pond that is separated from the sea by a sand berm. During the winter, this berm is often breached, flooding the otherwise freshwater pond with salt water.
- Heiau: A submerged Hawaiian heiau (temple), believed to be a shark heiau, is a primary park resource.
- Sharks: Three species of sharks are present in the bay and include grey reef sharks (*Carcharhinus menisorrah*), black-tip sharks (*C. melanopterus*), and whitetip reef sharks (*Triaenodon obesus*). Black tip reef sharks actively pup within the park.
- Threatened and Endangered Species - Turtles: Green sea turtles (*Chelonia mydas*) frequent park waters but do not usually rest on the park beach.
- Marine mammals: Humpback whales (*Megaptera novaeangliae*) and spinner dolphins (*Stenella longirostris)* are frequently seen in waters adjacent to the park. How much time these species spend within the park's waters is unknown. Other marine mammals observed in Kawaihae Bay, adjacent to the park, include false killer whales (*Pseudorca crassidens*), spotted dolphins (*Stenella attenuata*, locally known as kiko), bottlenose dolphins (*Tursiops truncatus*) and melon-headed whales (*Peponocephala electra*). The

Hawaiian Islands Humpback Whale National Sanctuary covers 3,626 square kilometers (1400 square miles of water) and includes waters off the park (the sanctuary stretches from Keahole Point to Upolu Point).

- Soft bottom community: Prior to dredging, Kawaihae used to contain a well-developed reef system. Today, active coral can be found only on the extremities of the bay. More commonly observed are marcroinvertebrate fauna, including polychaetes, bryozoans and crustaceans in the silted areas and some mollusks in the subtidal areas (Cheney et al. 1977).

KAHO

The legislated boundary of KAHO extends into the marine environment, encompassing 596 acres of submerged lands. These are technically under the jurisdiction of the State of Hawaii and the park has begun discussions with the state in hopes of pursuing a joint management agreement.

- Algae: KAHO has a highly diverse turf algal flora that is critical food for sea turtles. Relatively few macroalgae are thought to be present at the park; however, as with other areas, the amounts and types of known macroalgae will likely increase significantly as more systematic sampling occurs.
- Beaches: KAHO has several beaches that are important to visitors or to marine wildlife. Aimakapa Beach is heavily used by visitors. This beach also separates the fishpond from the ocean and is a popular site for basking green sea turtles. Iopio Beach has a significant cultural site, a Hawaiian heiau. This beach is experiencing significant erosion.
- Coastal and Submerged Volcanic Features: KAHO has a varied coastal geologic make-up, both intertidal and subtidal comprising several submerged geological features, including lava tubes, historic flows, and arches.
- Coral Reef: There is a range of coral habitat types at KAHO, ranging from extensive shallow benches or pavement in the south, to coral pinnacles, steep slopes and rich coral fields. Most of the coral reefs are typical of exposed areas on the Kona coast of the island of Hawaii (Big Island). Basalt benches and lava tubes colonized by isolated coral heads are present in the northern areas of the park. In the south area of the park, numerous coral pinnacles are present. These pinnacles are used heavily by visitors (SCUBA Divers) and sea turtles. Four boat moorings occur in this area.
- Fishponds: These cultural features form calm shallow embayments containing significant marine resources. They are connected to the ocean and likely serve as a significant nursery habitat for many coral reef species. The calm waters of the fishponds may also harbor species specific to this environment, which does not occur elsewhere within the park or along the Kona coast.
- Intertidal: The intertidal zone at KAHO is typical of other intertidal areas along the Kona coast. KAHO has several tidepools that are heavily used by visitors, and that require management. Tidepools serve as a valuable nursery for some coral reef animals. Endemic Hawaiian limpets (opihi) were found historically in the park; shells are found in middens; low densities of predominantly small individuals are present. Cowry beds

(probably the endemic *Cypraea sulcidentata*), or areas where these snails are unusually common are present in the park and large numbers of these shells can frequently be found in the intertidal region.

- Marine Mammals: A pod of spinner dolphins (*Stenella longirostris*) occasionally rests in park waters near the mouth of Honokohau Harbor. Humpback whales (*Megaptera novaeangliae*) are present seasonally within the park. Monk seals (*Monachus schauislandi*) are occasional visitors. While seals have historically used the beaches at KAHO, at present no seals haul out within the park.
- Sea Birds: Wedgetail shearwaters (*Puffinus pacificus*, uau kani) nest in the park.
- Soft Bottom: Several large soft bottom areas occur within the park. These relatively unexplored regions probably contain significant species diversity and important habitat for many groups of animals, including soft-bodied invertebrate, fish, and some algae.
- Threatened and Endangered Species - Turtles: Two species of turtles, hawksbill (*Eretmochelys imbricate*) and green sea turtles (*Chelonia mydas*), frequent park waters. Hawksbills have historically used beaches within the park for nesting. Green turtles routinely bask on the beaches. Both turtles feed in park waters.

PUHO

The legislated boundary of PUHO does not extend past the high tide line. There are several significant marine resources in the park.

- Basalt Shore/Cliffs: PUHO has a primarily basalt shoreline with small pockets of carbonate sand beach. Beaches are primarily in the northern part of the park, while the southern shores are sheer basalt cliffs and platforms. Birds visit the cliffs as evidenced by guano markings, but their identity and whether they are nesting is currently unknown and studies are currently being conducted. These southern cliffs may also contain significant cultural artifacts (e.g. burial caves), but survey data are lacking. Endemic Hawaiian limpets (opihi) are probably rare in the park despite the fact that the basalt habitat along this shore is extensive and ideal for these highly-prized endemic species; old shells occur at a former fishing village site within the park. Shoreline gathering is also a management concern.
- Coral Reef: An extraordinary and well-developed coral reef ecosystem occurs in Honaunau Bay immediately adjacent to the park. Soft sediment is widespread at the base of the fore-reef slope, as is the case off much of the Kona coast of Hawaii Island. Offshore and to the south are large areas of coral colonized basalt habitat. Both areas have abundant and diverse fish assemblages.
- Threatened and Endangered Species - Monk Seals: No monk seals (*Monachus schauislandi*) currently use the park, but adequate evidence exists that these endangered animals once occupied this area and may have used beaches within the park. As the monk seal population continues to expand, individuals are returning to former areas of occupation in the main Hawaiian Islands, and monk seals may become a significant management concern in the future.

- Threatened and Endangered Species - Turtles: Green sea turtles (*Chelonia mydas*) frequent the waters adjacent to the park and often pull out onto the beaches. However, no nesting has been documented within the park. Turtles are consistently observed on the beaches throughout the year.

HAVO

While the legislated boundary of HAVO does not extend below the high line, several significant marine resources occur along the HAVO coast.

- Coastal Volcanic Features: The coastline of HAVO is composed of recent lava flows and consists of numerous recently formed volcanic features including high basalt cliffs, basalt benches, and black sand beaches of volcanic origin. Some of these features are short-lived or physically unstable due to their recent formation, geological structure, or ephemeral nature. While unique, it may not be possible to include these areas in a long-term monitoring program, but remote sensing, land-, and boat-based monitoring techniques may be possible. Working near many of these features is hazardous and safety must be the utmost concern.
- Intertidal: HAVO has large stretches of high coastal basalt cliffs, as well as basalt benches, tidepools and sand beaches. Endemic Hawaiian limpets (locally known as opihi) occur in some intertidal areas. These and other intertidal organisms are important traditional foods for Native Hawaiian communities adjacent to the park.
- Threatened and Endangered Species - Turtles: Hawksbill turtles (*Eretmochelys imbricate*, federally listed as endangered) frequently nest on beaches within the park. Turtle nesting has been observed at three beaches: Halapae, Keauhou Landing, and Apua. Apua has the longest history of documented nesting and is also the most consistent, occurring every year. The park has only recently started observing nesting at Halapae and Keauhou, so data at these beaches is limited. Data for other beaches does not exist.

ALKA

Seventeen percent (17%) of the trail lies within the other four NPS units (HAVO, PUHO, KAHO, and PUHE) located on the island of Hawaii. These NPS-owned trail segments are included in the I&M initiative relative to each of these park units, the resources listed (please see above) for these units are relevant and applicable for ALKA. The remaining 83% of the trail is not owned by NPS and traverses other federal, state, county and private land holdings. The exact location and extent (width) of this trail have not yet been determined. The following resources were of particular importance for this park unit, particularly since this extensive coastal park would encompass a diversity of ecosystems that support sensitive organisms, a high priority for the National Park Service.

- Threatened or Endangered Species: These include hawksbill (*Eretmochelys imbricate*) and green sea turtles (*Chelonia mydas*), humpback whales (*Megaptera novaeangliae*), Hawaiian monk seals (*Monachus schauislandi*).
- Beaches and intertidal areas: Beaches and intertidal areas provide areas for migratory shorebirds to rest. Black and green sand beaches are also a unique resource and valuable

for nesting sea turtles. Intertidal areas contain a wealth of marine resources both important aesthetically and culturally. Shoreline and spear fishing are common marine activities, in addition to gathering salt, seaweed (locally known as limu), and endemic limpets (opihi) from rocky shorelines.

- Coral reefs: Extensive coral reef formations off the Kona coast offer habitat for assortment of species, among them many species of fish, invertebrates and seaweeds.

NATURAL RESOURCE ISSUES

Land Use

Any action that requires the alteration of the surrounding land's vegetation or physical characteristics will result in some detrimental impact to surrounding waters. If not conducted in an environmentally conscious manner, land use, including urbanization, can lead to significant impacts on nearshore marine ecosystems. Parks: All

Groundwater

Groundwater is a significant source of fresh water into the nearshore marine environment at all Pacific islands and parks. Groundwater is the below-ground reservoir of water in, and flowing through porous soils, rock, or cave/lava tube systems. Changes in quantity and quality of groundwater entering marine ecosystems can have significant localized effects on seawater temperature and salinity. Groundwater can also directly affect marine organisms by lowering salinity and temperature, as well as acting as a significant transport mechanism for land based sources of nutrients, contaminants, and possibly sediments. Poor land management can lead to significant changes in the quality, volume and movement of groundwater that can significantly impact nearshore marine communities, particularly in the tropics. Parks: ALKA, AMME, HALE, HAVO, KAHO, KALA, NPSA, PUHE, PUHO

Surface Flow/Runoff

Besides ground water and direct precipitation, the other primary source of freshwater into the nearshore marine environment results from surface flow or runoff. Surface flow can occur in existing stream (or man-made) channels, by sheet flow over the surface, or by heavy precipitation eroding and cutting new – temporary or permanent -- water courses. Like groundwater, surface flow can directly affect marine organisms by reducing salinity and temperature (particularly at point sources, e.g., stream mouths), as well as act as a significant transport mechanism for nutrients, contaminants, and sediments where sources, including harbors, exist. Poor land management practices can lead to significant changes in the composition, volume and movement of surface waters. Parks: ALKA, AMME, HALE, KAHO, KALA, NPSA, PUHE, PUHO, WAPA, USAR

Contaminants

Many land uses have associated contaminants that can find their way into nearshore waters through point or non-point source releases (e.g., chronic [e.g., septic tanks], fuel tank leaks, acute spills, dumping, boat cleaning), via surface runoff or groundwater. Contaminants vary depending on the nature of the land use. For example, industrial areas may introduce a variety of chemical compounds to the environment; agricultural areas can be sources of fertilizers (nutrients), pathogenic microbes from animal wastes, and pesticides; and residential areas may be sources of nutrients, pesticides and hydrocarbons, among others. Lastly, some contaminants may come from natural sources or processes as when released by erosion, volcanic activity, or other geologic processes. Parks: ALKA, AMME, KAHO, KALA, NPSA, PUHE, PUHO, WAPA, USAR

Fishing/Collecting

Fishing refers to catching or harvesting of any marine biological organism, either living or dead, or its remains. A wide diversity of species are harvested in the Pacific, including numerous species of fish, turtles, echinoderm, mollusc, crustaceans, algae, among other animal species. Fisheries may be for consumption or non-consumption, commercial or subsistence. For this report, the collection of coral skeletons and live rock are considered fisheries. Parks: ALKA, HALE, HAVO, KAHO, KALA, NPSA, PUHO, WAPA

Commercial fishing, including live fish fisheries (fish delivered live for the restaurant trade), charter sport fishing, and relatively small scale local artisanal take, is the extraction of marine organisms (e.g. fish, algae, live rock, invertebrates, etc.) intended for non-subsistence or non-personal use where the products appear on the open market for sale or trade or are obtained with the services of a fishing guide or charter fishing vessel. Commercial fishing is not allowed within a National Park unless specifically mandated by the park's enabling legislation. No PACN National Park allows commercial fishing. Parks: NPSA, WAPA (banned but suspected)

Recreational fishing is the act of harvesting any marine organism for personal use without its sale or trade on the open market. Recreational fishing, as distinguished from traditional fishing, usually does not occur using indigenous cultural methods, rather with modern equipment and techniques. This type of fishing may be for recreation or personal use. Parks: ALKA, HALE, HAVO, KAHO, PUHO, NPSA

Traditional, Cultural, and Subsistence fishing may or may not be done using long-standing cultural practices, techniques or tools. Tools and techniques may be traditional but not necessarily cultural. Fishing for subsistence may use techniques or tools that are cultural, modern, or a combination of the two. Cultural fishing may not necessarily be for subsistence and subsistence fishing may be done simply to subsist and not necessarily for cultural purposes. A distinction is made between Traditional and Recreational fishing because several National Parks, including many Pacific Island Parks are mandated to allow traditional fishing to occur within their boundaries. Moreover, many NPS units were establilshed to preserve cultural practices and have as a primary purpose the promotion and interpretation of traditional cultural values and lifestyles. In many cases, due to the nature or scale of their practice(s), traditional fishing has less impact on nearshore marine ecosystems than do modern techniques usually employed by recreational or other fisheries. Parks: ALKA, HAVO, KAHO, KALA, NPSA, PUHO, WAPA

The aquarium trade fishery is a worldwide, large and rapidly growing commercial industry in which species are sold to aquarium hobbyists, often for considerable profit. These fish and invertebrates are not consumed and the fishery targets mainly coral reef species and age classes that survive well in captivity. Many of these fisheries focus on small adult or juvenile individuals. As a commercial fishery, this fishery is not allowed to occur within any National Park. Parks: ALKA, KAHO (banned but suspected)

Recreational Use

Recreational use covers a wide range of human activities in or adjacent to the marine environment. For this report, fishing, a common recreational activity, has been discussed separately above because it can occur as a non-recreational activity and is generally managed by parks, states and territories differently than other recreational activities.

Boats can have significant direct impacts on the marine environment. Groundings cause mechanical damage to the reef or bottom, breaking corals and ripping up algae or seagrasses. Boats are sources of contaminants in the water, from anti-fouling paints to hydrocarbons and other organics, and can act as vectors for exotic and invasive species. Anchoring can be a significant problem in areas where permanent moorings are not available. Boats can also increase impacts from fishing or SCUBA by allowing access to areas that may be inaccessible from land. Parks: ALKA, AMME, HAVO, KAHO, KALA, PUHE, PUHO, WAPA

Harbors can have significant impacts on nearshore ecosystems. Concentrations of boats can lead to increased chances of vessel groundings, sewage, contaminants, and fuel discharges, and recreational and fishing activities. Harbors, Marinas and Boat Ramps are often significant point sources of contaminants that can accumulate in sediments. Harbors are often the point source for marine invasive species. Parks: ALKA, AMME, KAHO, PUHE

Diving involves the use of SCUBA equipment, either from land or from a boat for recreation, fishing (recreational or otherwise), commercial (e.g., salvage, underwater construction), scientific research, resource management, law enforcement (e.g., SAR), or other purposes. While fishing can occur using SCUBA equipment, this activity is treated as a form of recreational fishing for this report. Parks: ALKA, KAHO, WAPA

Jet skis are distinguished herein from other mechanized watercraft (e.g. boats) because jet skis can enter areas usually inaccessible to larger craft, and may often be subject to special local legislation in efforts to reduce conflicts with other water uses and to lessen environmental impacts. Jet skis have been involved in collisions with swimmers, divers and other vessels or structures. In many states and territories jet skis are restricted to specific areas. Impacts from jet skis include collisions with and physical damage to organisms (e.g. turtles, marine mammals) or the bottom, and leaking of hydrocarbons into water and air. Parks: None, presently.

Feeding of animals can cause behavioral changes, habituation to and dependence on feeding by humans, and can create public safety risks. Feeding animals reduces animal wariness toward humans and may cause animals to become a nuisance, requiring management intervention. Animal densities also tend to increase around feeding sites leading to a disruption in the natural structure and processes of communities. Feeding of reef fishes by tourists and dive guides was common in the past. This practice has been discouraged through educational efforts or banned in many jurisdictions, but it is still common in some areas of the Pacific (e.g., Guam). Feeding of any wildlife is prohibited in National Parks. Parks: None, presently

Recreational beach activity is an important feature at many PACN National Parks. Beach activity can include picnicking, swimming, snorkeling, body-, boogie-, or board-surfing, kayaking, canoeing, and overnight camping, depending on local and park regulations. Human use of beaches and associated nearshore ecosystems can produce significant impacts on marine ecosystems, including impacts from trampling, disruption of nesting or haul-out/resting by birds, turtles or mammals, fishing, SCUBA diving, solid waste, light or chemical pollution, etc. Parks: ALKA, AMME, PUHO, WAPA, NPSA

Sedimentation

Sedimentation can directly impact sessile benthic organisms, especially corals, by decreasing oxygen and light, ultimately smothering them. Sedimentation can also increase water turbidity, lowering light levels and affecting photosynthesis rates. Corals can be particularly susceptible to poor water quality. Sedimentation is a natural process in nearshore environments and is directly affected by terrestrial runoff and oceanographic conditions. Parks: KAHO, NPSA, PUHE, WAPA, USAR

Sewage

Sewage in this report refers to waste water containing fecal material and associated microbes from land animals, including humans. Sewage is a significant source of nitrogen and other nutrients. If sewage discharge to coastal waters is chronic or prolonged it can promote the rapid growth of some marine organisms and cause an observable phase shift in the community structure of nearshore ecosystems (e.g., change from coral to algal dominated communities). Human sewage often receives some level of treatment, whereas animal sewage is generally untreated, and in the case of feral animals, the magnitude of the input to coastal waters is usually unknown. In some areas sewage may be released from household septic tanks through ground water to coastal waters at low but chronic rates. Parks: ALKA, AMME, KAHO, KALA, NPSA, WAPA, USAR

Human sewage can sometimes be traced to a source, whether sewage treatment plants, marinas, vessels, septic tanks, or streams. Human sewage is never considered a natural component of nearshore ecosystems and is required by law in most jurisdictions to be treated prior to release in the ocean as sewage contains pathogenic organisms causing a variety of diseases.

Animal sewage can sometimes be traced to point sources (e.g., piggeries, bird colonies) but also may be diffuse and result from terrestrial runoff. Animal sewage impacts may be of natural origin, for example, a sea bird colony, and while having a significant impact on the marine environment, are a natural component of the nearshore ecosystem. Some animal sewage also carries disease.

Solid Waste

Litter can be a significant problem in the marine environment. Trash discarded from vessels or shore can collect on the bottom and cause a public health or safety hazard, create a visual eyesore to visitors, or degrade the environment. Some litter, plastics in particular, whether on the bottom, floating in the water column or on the surface, may be consumed by wildlife, potentially killing animals. Litter has received considerable public attention over the years and many areas conduct public beach or reef clean-ups to remove litter from popular swimming and diving sites. Parks: ALKA, AMME, HALE, KAHO, NPSA, PUHE, WAPA

Landfills can be a significant source of solid waste and other contaminants in the marine environment. Solid waste can be blown or washed into the ocean by winds or storms. Contaminants usually enter via runoff or groundwater. Currently, EPA regulations do not allow the development of landfills in the coastal zone, but old landfills may still exist in close proximity to the ocean. American Memorial Park has a coastal landfill adjacent to its boundary (recently closed by CNMI). NPSA has a small dump near the beach on Ofu Island that is being cleaned up. Parks: ALKA, AMME, KAHO, KALA, NPSA

Marine debris is solid waste originating from a marine source such as a ship or other vessel but may also include waste that has been adrift for a long time and whose actual origin is unknown. This debris, including relic fishing nets and floats, barrels, bottles, plastics, trash, rope, processed wood, etc., can drift considerable distances over the open oceans. Debris, in addition to causing damage similar to can aid in the introduction of invasive or alien species. Parks: ALKA, HALE, KAHO, KALA, PUHO, WAPA

Light

While often considered a night sky issue, light pollution can have a significant effect on wildlife. Many organisms use the night sky as a navigational aid or require darkness to successfully reproduce or grow. The presence of artificial lights shining in or on the ocean may also attract species at night, particularly plankton, which in turn may artificially attract and concentrate planktivorous species in the vicinity. Lights along the beach may discourage sea turtles from nesting or disorient hatchlings and prevent them from moving to the ocean. At this time, the ecological significance of light pollution on the marine environment is not well understood or documented. Parks: AMME, WAPA, USAR

Local Weather, Climate, and Tides

Local weather and climate conditions at each park interact with natural and anthropogenic factors at several scales to affect the nearshore marine environment, by changing the physical conditions or chemical composition of nearshore waters. These environmental changes can have significant effects on oceanographic and ecological processes and the species composition of nearshore ecosystems. Climate and weather influences cannot be managed per se. However, there must be an awareness of these conditions and their effects on resources specific to each park in order to effectively manage those conditions or aspects that are manageable, to protect resources or to mitigate potential damage. Parks: All

Large or chronic rainfall events can significantly change the salinity, temperature, and amounts of dissolved or particulate matter (e.g., sediments, contaminants) in nearshore waters. Many coral reef organisms are sensitive to small changes in all of these parameters.

While there is generally a small range of variation in air temperature in the tropics, periods of high temperature can have significant effects on organisms in shallow water. Long periods of warm weather can heat shallow water areas; when these periods of elevated temperature coincide with low tides, exposed organisms become particularly susceptible to sublethal stressors or experience mortality from temperature, desiccation, ultraviolet radiation exposure or a combination of these. Although many tropical organisms have heat-resistant enzymes and other adaptations (e.g., sunscreen compounds), corals in particular are susceptible to small increases in water temperature or to high air temperatures if exposed.

Wind can transport and deposit airborne particulates and pollution into the ocean. Airborne particles can travel great distances, sometimes originating from hundreds to thousands of kilometers from where they are deposited in or on the water. For example, airborne dust carrying pathogenic microscopic organisms from Saharan Africa has been hypothesized as a potential source of coral disease in the Caribbean (Shinn et al. 2000). Wind can also directly affect organisms by increasing the desiccation rate of exposed animals, or by forcing turbulent water movements that can physically damage organisms in nearshore waters.

Cloud cover has direct, short-term, transitory effects on the amount and quality of light reaching the ocean. Changes in solar radiation (including ultraviolet, photosynthetically active region and infrared radiation) can have significant impacts on the community composition, structure and function of nearshore ecosystems.

Compared with areas at higher latitudes, tropical Pacific areas have low, or micro-tidal ranges, often varying a meter or less between high and low tide extremes. Regardless, tidal range can have a significant effect on marine organisms, especially if low tides expose animals during hot daylight hours, times of significant rainfall, or during catastrophic accidents, such as oil or contaminant spills.

Alien and Invasive Species

As in terrestrial environments, alien and invasive species can have profound effects on the structure and function of marine ecosystems. Unfortunately, the type(s) and extent of marine alien or invasive species distribution and abundance are only just beginning to be determined. Alien and invasive species can be transported in ballast water, as fouling organisms on hulls (Godwin 2003), or can be accidentally or intentionally released by humans. Park areas closer to harbors or areas of vessel traffic are generally more susceptible to introductions. In contrast, areas on exposed outer coasts or areas with limited contact with vessels or harbors have less vulnerability to introductions of these aquatic nuisance species Parks: All, presumably.

Invasive and alien algae are a well-documented, severe ecological and economical threat on several Pacific Island reefs. Several algal species have been implicated in problems and damage to coral reefs (Smith et al. 2002, Smith 2003, Smith et al. 2004). Areas with high nutrients from natural or anthropogenic sources are particularly problematic (Dollar 1999, Stimson et al. 2001), but nuisance seaweeds occur in low nutrient conditions as well. Experiments are underway that will hopefully develop effective methods of management, control, or removal for these species.

Numerous species of fish have been introduced to nearshore marine environments but their ecosystem impacts are often unknown or unclear. Many of these species have been intentionally introduced to develop fisheries and are believed or known to compete with ecologically similar native species. Examples in Hawaii include snappers (Taape, Toau) and a grouper (Roi).

Little is known about invasive marine invertebrates other than their presently known distributions. To date relatively few of these animals have been documented outside of Hawaii. Even within Hawaii, their impact on the nearshore reef environment is not well known. However, alien or invasive invertebrates have the potential to exclude native counterparts from intertidal zones, reef flats and other protected habitats. Very deep reefs containing precious coral species in Hawaii have recently been documented to be severely impacted by an invasive soft coral, which apparently has deleterious effects on recruitment, growth and survival of black coral and closely related species.

A recent study by the Bishop Museum (Coles et al. 2004) investigated the impact of invasive species on coral reefs in Hawaii and results were similar to other studies on Guam (Paulay et al. 2003) and American Samoa (Coles et al. 2003) in that there was a low frequency of occurrence of invasive alien species on the coral reefs. They recommend that research should focus on preventing initial introductions, particularly in embayments, which had the greatest frequency of occurrence.

Bioprospecting

While not currently known to be a significant problem, marine bioprospecting, or the removal of organisms (microbes, plants, or animals) containing biochemical compounds of potential or known biomedical or pharmaceutical application, may cause significant damage to marine ecosystems. Natural products from marine organisms are currently being researched or are in clinical trials for cancer treatments, sunscreens, and other commercial products. While these are of potential tremendous benefit, bioprospecting has the potential to decimate populations of the species of interest, as many of these compounds cannot be easily synthesized and organisms would need to continue to be harvested from the wild. While some precedence has been set in the NPS regarding bioprospecting, marine bioprospecting must be approached with caution and should be addressed, with appropriate management policy and regulatory approaches, prior to marine bioprospecting becoming a significant issue. Parks: None known at present.

STRESSORS AFFECTING EACH PARK

WAPA

- Alien and Invasive Species: WAPA has not had a comprehensive baseline inventory of the marine environment and the presence or absence of alien or invasive marine species is not adequately documented within the park. However, recent survey work has documented the presence of alien species on the island (Paulay 2003) and the potential for these ecologically and economically destructive species to be present in the park is high. Therefore it is urgent that the nearshore environments in the park be surveyed to assess the identity, distribution, and abundance of any alien or invasive species, in order to formulate management strategies.
- Beach Activity: The Asan unit of WAPA is a popular recreational area with limited beach use. The fringing reefs are not ideal for leisure bathing but some does occur throughout the year. Any impacts from bathers are assumed to be low.
- Boating: Some boating occurs within the park boundary, usually in connection with commercial SCUBA diving tours and dolphin watching. Boats also transit through the park units. A marina (Hagatña Boat Basin) is upstream of the Asan Beach unit. A second marina (Agat Marina) is adjacent to, but downstream of the Agat Beach unit. New Homeland Security measures enacted in Apra Harbor on July 1, 2004 have made it more difficult for SCUBA tour companies to use the harbor (both for mooring vessels and diving), forcing several of the companies to relocate their harbor operations to smaller boat basins and to seek alternative dive sites outside of Apra harbor. Park staff

have noted an increase in dive boat operations in the park, which currently does not have adequate mooring buoys in place to handle the increased traffic.

- Contaminants: Contaminant levels within the park are unknown but past activity in the region suggests that chemical and heavy metal contaminants may be present. PCBs were found in fish tissues just north of the Agat unit in 2002, but EPA testing conducted at the park boundary found no evidence of PCBs. Evidence of tributyl-tin contamination is present in Apra Harbor, which lies between the Agat and Asan Beach units.
- Fishing/Collecting: According to WAPA's agreement with the territorial government, the park must allow access for traditional subsistence fishing in accordance with territorial laws. Fishing is conducted for a wide variety of species, ranging from fish to invertebrates to algae. Because of the park's proximity to population centers and ease of access to the ocean, fishing pressure in both the Agat and Asan Beach units is among the highest on the entire island. Observations made by park staff suggest the intensive fishing, which has been estimated at 30,000 fisherman-days per year, is having a noticeable effect on the nearshore environment. In addition to having direct impacts on target fishery species, fishing is also contributing to debris, predominantly lost gear and tackle, and to reef trampling.
- Land Use/Development: Guam zoning regulations are poorly enforced, and human development comes to the very edge of the park boundary. Guam also does not have an approved Coastal Zone Management Plan, so regulations overseeing development along the coast are not complete. The primary north-south road on the island runs directly adjacent to park waters, often only a few meters from the water's edge. Several buildings have been constructed along the coast, and many abut directly on the water, built out on the seaward edge on sea walls. Development in the watersheds above both the Asan and Agat Beach units is considerable and anti-erosion regulations are inconsistently enforced by the local regulatory agency during construction.
- Light: Land development directly adjacent to the waters of the Agat and Asan beach units has led to increased coastal light pollution. Currently, effects on the park marine resources, if any, are not known.
- Litter: Litter is a significant problem at both the Agat and Asan Beach units. Aluminum cans and other litter are visible on the bottom as deep as 25 m. Following storms, beaches are covered with washed-up litter. Local SCUBA tour operators have removed over 100 kg of litter from the popular dive sites within the park. The ecological effects of the solid waste on the park's resources are not known.
- Marine Debris: Marine debris is not a significant problem within the park except following storms. Stormy weather washes floating debris onto the shore. Otherwise, debris appears to stay predominantly offshore and out of park waters.
- Population Outbreaks: In the 1970s, an outbreak of the Crown-Of-Thorns Seastar did considerable damage to Guam reefs, including reefs within WAPA. Currently, COTS densities are low, but the potential for an outbreak remains.
- Overland Flow/Runoff: WAPA currently experiences high rates of runoff during rainfall events. Surface waters flood streams and form significant point sources of fresh water

entering coastal waters. Non-point source runoff (e.g., from roads, non-vegetated land), is most likely a significant source of nutrients, contaminants, and sediments into the nearshore marine environment.

- Relic Military Equipment: WAPA encompasses the two amphibious landing beaches used by the US military during the liberation of the island of Guam from Japanese occupation in 1945. Military equipment and ammunition are frequently found on the bottom, often heavily encrusted with coral growth. An extensive ammunition dump off Camel Rock (reportedly with 64 tons of unexploded munitions) is within the park's boundary. This submerged ordnance, here and possibly elsewhere, poses a safety risk, primarily to park personnel working in these areas. Metal from relic equipment can have localized but significant ecological effects on the community. For example, iron enrichment can sometimes stimulate rapid growth of some blue green algae that can overgrow and kill surrounding coral and other sessile organisms.
- SCUBA Diving: At least one popular dive site is within the park boundary and receives several commercial diving tours per day. Other sites also exist in the park, as evidenced by mooring lines in the Asan Unit. Prior to July 2004, these sites appeared to be seldom visited by commercial operators, but recent Homeland Security related changes at Apra Harbor may be causing an increase in their usage. While it is unclear if animal feeding occurs in the park, several of the local dive tour operators routinely engage in fish feeding. Mooring lines are available at the popular dive sites, but often the number of boats on-site exceeds the number of moorings and boats drop anchor, potentially damaging the reef.
- Sedimentation: Sedimentation has been identified as the most significant threat to Guam's coral reefs. No baseline data exists for sedimentation rates into park marine waters, but the park staff routinely observe high sediment conditions in the waters of both the Agat and Asan units. Work is currently underway to gather baseline sedimentation data for the park.
- Sewage: The Hagatña Sewage Treatment Facility is upstream from the park boundary and its outfall pipe is in relatively shallow water. Typhoon Pongsoña (Dec 2001) damaged the discharge pipe, which has yet to be repaired, resulting in sewage discharge at a shallower than intended depth. Up until recently (2001), the Agat Sewage Treatment Facility dumped effluent directly within the Agat unit of WAPA. This facility has been closed and the effluent from this facility is now released through a deepwater outfall to the north of the Agat unit. EPA water quality monitoring consistently finds impaired waters within the boundary of both the Agat and Asan units.
- Typhoons: Typhoons or a constant periodic and natural stressor to Guam's marine environment. Typhoons that have passed over or near WAPA since 2000 include Saomai (2000), Chata'an (2001), Halong (2001), Pongsoña (2001), Tingting (2003), Chaba (2003), and Songda (2003).

AMME

- Alien and Invasive Species: AMME is in the process of inventorying its mangrove and wetland ecosystems and until that is complete, the severity of the invasive species problem is unknown. However, the potential for these ecologically and economically destructive species to be present in the park is high and it is urgent that the park assess the distributions of alien or invasive species and formulate management strategies after the initial inventories are completed.

- Boating and Marina: The large public marina adjacent to the park and within its boundary is the primary harbor for small private craft on Saipan. Presently, boats represent a relatively minor threat to AMME's marine resources, but have the potential to cause significant impacts. Boats can ground, spill hydrocarbons or be a source of nutrients.
- Contaminants: Contaminant levels within the park are unknown. Water quality monitoring adjacent to the Saipan Landfill has found no evidence of contaminants leaching from the dump into the marine environment. Data are lacking for groundwater and hence contaminants may be a significant problem in the park. The presence of the landfill, a large public marina, a canal that drains a commercial area of the town of Garapan, the presence of solid waste including suspicious 55 gallon drums, and a wastewater outfall from the Hyatt Resort all suggest that contaminants may be present in the nearshore and wetland sediments. The Army Corps of Engineers (US Army Corps Engineers 2004) recently completed a fuel remediation project for hydrocarbons in the soils in and adjacent to the park resulting from a military vehicle pool that existed on park lands.
- Erosion: Erosion has been documented at the beaches within AMME, but it is currently believed to be a natural phenomenon. The Army Corps of Engineers conducted an assessment and made management recommendations to reduce beach erosion, but recommendations need to be carefully reviewed for their environmental impacts before implementation. A document generated for the park in 1990 discusses some of the historical changes in shoreline patterns and makes recommendations to stabilize the shoreline (Dean 1991). However, dire predictions from this document have not been unfolding, suggesting that the shoreline may be reaching a stable state. Work has been started by park staff to assess the rate of beach erosion at the park.
- Groundwater: Groundwater is important to the marine resources of AMME. In particular, the mangrove forest is dependent on some freshwater input. The island has undergone considerable development and the quantity and quality of groundwater flowing into the park's mangrove areas has probably been altered. The park has secured funding to begin preliminary assessments of groundwater resources associated with the wetland in fiscal year 2005.
- Landfill: The Puerto Rico Landfill was closed in 2003 but the age of the landfill and its proximity in the coastal zone immediately adjacent to the ocean makes it a significant threat to water quality and a potential source of contaminants, bacteria, and nutrients.
- Land Use/Development: AMME is an urban park surrounded by considerable human development. The park itself is heavily developed, with only a small "natural" area: a wetland at the east end of the park. Major roads form the park's boundaries on land; beaches and a marina are present within the park waters. A large amphitheatre also exists within the park.

- Light: Land development directly adjacent to AMME has led to increased coastal light pollution. The NPS has also installed lights along a popular beach-side walking path within the park. Currently, effects on the park marine resources, if any, are not known.
- Litter: Litter is a significant problem throughout AMME. Illegal dumping creates small dumps within the park. Large events, frequently held within the park, contribute to the litter problem. Feral animals contribute to the solid waste problem by knocking over trash cans and bringing litter into the park.
- Overland Flow/Runoff: Overland Flow is important to the marine resources of AMME and may be the principle mechanism recharging the inland mangrove wetland. This mangrove stand is dependent on freshwater input. Runoff from the surrounding urban areas may transport nutrients and other contaminants.
- Sewage: Saipan has a systemic sewage problem. Current treatment facilities are not capable of handling the volumes associated with heavy storm events, and raw sewage is often bypassed into the nearshore waters, forcing beach closures. Also, the Hyatt Resort operates a wastewater treatment facility that dumps just outside of the park's boundary. Sewage contamination has repeatedly forced the closure of AMME's beaches. Feral animals also contribute to the sewage problem, but their impact is currently unknown.
- Typhoons: Typhoons are a constant periodic and natural stressor to Saipan's marine environment.

NPSA

- Alien and Invasive Species: Some alien or invasive species are present in American Samoa, but, based on recent surveys, most appear to be restricted mainly to Pago Pago Harbor. None have been reported yet from nearshore waters in any park unit. Currently alien and invasive species do not appear to be a problem in the park; however, they have the potential to become a significant stressor.
- Contaminants: While little contaminant works has been conducted at NPSA, potential sources and transfer mechanisms do exist. A village landfill lies adjacent to the Ofu Unit, which is supposed to be cleaned up.
- Disease: Over the last few years, the natural resource staff at NPSA have noticed an increase in the presence of coral disease and disease-related mortality, including at least one newly recognized disease that was first sighted on the Great Barrier Reef (called "white syndrome"). Studies of coral diseases in the territory were initiated in 2002 and are on-going. Potential impacts of coral diseases can be of serious consequence (e.g., widespread diseases in Caribbean reefs).
- Fishing/Collecting: Overfishing is a primary stressor to coral reefs throughout the territory, including NPSA. Few large fish (greater than 40 cm) remain on coral reefs. In NPSA, fishing is primarily for subsistence, and the catch is modest. However, a recent study suggested that as much as 9% of the local commercial (artisanal) catch of reef fishes were illegally taken from park waters. American Samoa has fishing regulations that ban such activities as scuba fishing and destructive fishing techniques, but

enforcement is not strong. A recent study documents the subsistence fishery occurring in the Ofu and Olosega park units.

- Global Climate Change: Global warming has been identified as on of the most serious stressors at NPSA. In addition to increases in seawater temperature for shallow water habitats which can be lethal to corals, increases in dissolved CO2 would reduce calcification rates and thus reduce coral growth rates.
- Groundwater: Mountainous areas in American Samoa receive 508 centimeters of rain per year, some of which enters the groundwater system. Freshwater seeps are present throughout the islands, and have been observed at several places in NPSA. The size or flow of these seeps is currently unknown.
- Hurricanes: The Samoan archipelago averages approximately one hurricane every ten years. The last hurricane in 2004 did moderate damage to the reefs.
- Land Use/Development: American Samoa is developing rapidly. While most development is currently happening away from the park (primarily in Pago Pago and around the Tafuna plain on Tutuila Island), development of more remote areas is occurring to a lesser degree. Plans to expand the Ofu airport runway could adversely affect the nearshore marine environment in and adjacent to the park. In addition to urbanization, agricultural (plantation) land is spreading up the steep hills and mountain slopes to meet food demands of the expanding population. Farming on the steep slopes has resulted in a concurrent increase in erosion, and, in some cases, runoff.
- Landfill: A small village dump is just upland of the beach in the Ofu Unit. This village landfill contains domestic garbage as well as old car batteries, refrigerators, and fifty-five-gallon drums (old fuel containers).
- Litter: Solid waste is an issue primarily in and around the villages. Solid waste washes from streams into coastal waters. Overall, this is a minor problem in NPSA, but can be locally significant.
- Population Growth: The population of American Samoa is expanding at a high rate (2.1% per year). Approximately 1,500 people (babies and immigrants) are being added to the islands annually. This rapid growth strains the marine environment in many ways (e.g., increased harvest, sedimentation)
- Population Outbreaks (Crown of Thorns): In the late 1970s, an outbreak of the Crown-Of-Thorns Seastar did considerable damage to Samoan reefs, including many in the park. Currently, COTS
- Sand Mining: Sand mining is a common practice, particularly on Ofu where sand is used to repair roads. Significant amounts of sand can be removed from beaches and other coastal areas for this activity.
- Sedimentation: Sedimentation occurs in the park, but at this time is not considered to be a serious issue. As development expands, and land use practices change, upland erosion and thus sedimentation will become more important impacts to the nearshore marine environment.

- Sewage: Both human and animal waste may at times be a significant problem within the park. Most villages are on cesspool systems. Piggeries are present, often near stream courses in some villages within the park, and on adjacent lands. Sewage problems are particularly evident on southern Tutuila where population densities are the highest.

USAR

- Alien and Invasive Species: Pearl Harbor is the primary entry point for marine invasive species in the state of Hawaii. These species have been well documented, including those on the USS Arizona itself. Pearl Harbor's invasive species are a significant and currently unmanaged problem of enormous magnitude.
- Contaminants: Oil constantly leaks from the USS Arizona. Concern exists that the ship may at some time in the future disgorge a large quantity of oil into the waters of Pearl Harbor. Depending upon environmental conditions, this oil may significantly impact most of the parks submerged resources, but a large oil leak also will have significant ramifications outside the park boundary.
- Hazardous Gases: Methane and other gases have been released from the USS Arizona. The source of these gases is unclear, but may be related to decomposition of bacteria (possibly oil-consuming bacteria) inside the hull.
- Litter: Litter is a significant problem at USAR. Large rainfall events flush litter from nearby streams onto the two sunken vessels. Tourist visiting the vessels routinely loose objects over the side of the Memorial, including items such as sunglasses, cameras, and batteries. Staff at the USAR clean litter from the deck of the USS Arizona every two weeks.
- Oil Spills: Two major oil spills have occurred within Pearl Harbor, one in 1987 with over 100,000 gallons of aviation fuel spilling into Middle loch and one in 1996 with 39,000 gallons of bunker fuel spilling into the East Loch (Coles et al. 1997). Both spills had effects on marine or nearshore resources including mangroves and intertidal organisms.
- Relic Military Equipment: In addition to the primary cultural resources of the park being relic military equipment, munitions and other explosives are often found in and around the two sunken vessels.
- Sedimentation: Pearl Harbor receives large quantities of sediment from streams and runoff. More than 23 meters of silt sits on the bottom of the harbor. Silt can be re-suspended and settle on the hull, impacting the marine life living there.

HALE

- Alien and Invasive Species: In contrast to terrestrial resources, HALE is not known to have significant alien or invasive species concerns associated with its marine resources. However, the potential for these ecologically and economically destructive species to be present in the park is high and the park needs to formulate management strategies. Several highly invasive marine species are present on Maui, and some of them can invade the intertidal region (e.g., *Chthalamus proteus* barnacles). The effect of these intertidal invasive species on native species is currently being studied in Hawaii by investigators at the University of Hawaii.

- Fishing/Collecting: Fishing is primarily restricted to collecting endemic limpets (opihi). The opihi fishery is known to have a significant impact on opihi populations throughout the state, but no known data exists on the impact of the fishery on park resources.
- Land Use/Development: This issue appears to be relatively minor in the coastal areas of HALE, but some development is planned, including paving a parking lot and installing a sewage treatment wetland in the coastal zone in the Oheo Gulch area.
- Litter: In general, solid waste is not a significant problem for the HALE marine resources, but litter may be locally significant, especially in the Oheo Gulch area, which has high visitation and allows overnight camping.
- Marine Debris: Derelict fishing gear and other marine debris are a minor, but persistent problem.

KALA

- Alien and Invasive Species: Invasive and alien species are a persistent threat to all ecosystems in Hawaii. A recent survey showed the presence of some alien species on the reef (Minton and Carnevale 2004) but the park's information on the occurrence of alien or invasive species in its coastal area is incomplete, and they may be a significant problem. Mangroves are in the park, and are the subject of an intensive control-eradication effort.
- Boating: Boating is not a problem in park waters, with exceptions noted under fishing and collecting. The Coast Guard operates a single boat mooring that is sometimes used by private vessels.
- Contaminants: No contaminants work has been conducted in the marine waters or sediments of KALA. The presence of two old landfills on the peninsula and agricultural lands at the headwaters of streams suggest that contaminates may be an issue. The composition of the dumps is unclear and no contaminant work has been conducted at the park.
- Fishing/Collecting: Fishing is restricted to the residents of the Kalaupapa Peninsula, however boats belonging to non-residents are typically observed fishing within park waters. Overall, fishing pressure is believed to be low, except for removal of endemic Hawaiian limpets (opihi). The park has preliminary data that suggest opihi are heavily fished within KALA. On at least one occasion within 2003, a commercial fishing vessel was observed operating within the park boundary.
- Groundwater: As on all high volcanic Pacific islands, ground water seeps occur along the coast within the park. Changes in the flow, quantity or chemical composition of groundwater may have localized effects on the marine ecosystem. Communities near groundwater seeps in the marine environment may be quite different from surrounding areas. A new distributional record in Hawaii for a marine alga is currently known only from a fresh groundwater seep area above the spray zone on cliffs in the park.

- Landfill: KALA has two landfills, both of which are old and do not meet current EPA regulations. Neither is lined and both occur in the coastal zone. The older of the two dumps is near the ocean and is actively being eroded by the sea. Waves frequently remove old solid waste from the dump and deposit it along the shoreline and in shallow subtidal areas. Little is known about the contents of these dumps. This raises significant concerns that they may contain environmentally hazardous material.
- Marine Debris: Marine debris entangled on the reef and shoreline is a serious problem within the park. The park actively removes marine debris, and has documented damage to marine resources. While no large animals have been found trapped in the debris, with the increased use of the park by endangered monk seals and sea turtles, debris is a concern.
- Seasonal Weather: KALA, on the north shore of the island of Molokai, is subject to extreme ocean conditions. These predominant high surf and swell conditions have a significant impact on the marine environment, and limit times in which work can be conducted. Ocean condition has an important effect on the community composition of the nearshore ecosystems around Molokai (Jokiel et al. 2001).
- Sewage: Household waste from residents, State of Hawaii, and park staff on the Kalaupapa Peninsula goes into septic tanks. Circumstantial evidence in the intertidal zone suggests localized presence of high nutrients that may be associated with septic leaching. However, the park lacks conclusive data.

PUHE

- Boating: Boats, primarily small privately owned vessels, frequent the waters in and around the park. Kawaihae Harbor is close to the park, resulting in heavy vessel traffic and the potential for associated impacts (e.g., groundings, fuel or contaminants spills, vectors for introduction of alien or invasive species).
- Contaminants: Contaminant levels within the park have not been measured, but numerous potential sources exist in the vicinity. Most likely sources of marine contaminants include recreational and commercial vessels transiting to and from Kawaihae Harbor, runoff or groundwater flow from upland development, and runoff from a highway that runs through the park.
- Groundwater: The status of groundwater within the park is unknown. Ground water seepage into the pond and coastal areas could influence the marine environment. Upland development and septic tanks could be significant sources of groundwater contamination, potentially reaching nearshore habitats.
- Harbor: The harbor at Kawaihae, immediately up coast from the park, was recently expanded to handle large commercial vessels (e.g., inter-island freight barges) in addition to smaller private crafts. Little is known about the contaminants from this facility. The harbor break wall extends well out from land. Its construction and footprint have no doubt contributed to sedimentation and altered nearshore current circulation patterns, respectively.

- Invasive Species: Invasive and alien species are persistent threats to all ecosystems in Hawaii. While the park has little information on whether alien or invasive species occur in the coastal area, they are potentially a significant problem.
- Land Use/Development: Development has occurred on all three land sides of PUHE. Spencer Beach Park, a popular state park is just to the south, and Kawaihae Harbor lies to the north, Residential areas occur inland, intermixed with grazed pasture land. A heavily used state highway cuts through the park.
- Litter: Litter is a significant problem. Illegal dumping occurs in the gulches leading into the park and rains wash trash downhill into the pond and ocean.
- Seasonal Weather: In the winter, PUHE experiences higher rainfall and winter surf compared to the summer. Winter storms break the sand berm separating the pond from the ocean and cause salt water to enter the pond.
- Sedimentation: Waters off PUHE experience high rates of sediment input from upland erosion. Marine derived sediments were a problem when the Kawaihae Harbor was constructed and dredged, and this will continue to be a problem whenever periodic maintenance dredging of the harbor occurs. Sedimentation from terrestrial erosion and runoff comes through the two gulches that open into the park and is a serious problem. The Army Corps of Engineers has proposed installing sediment containment systems.

KAHO

- Boating: Boating activity is a significant stressor to park resources. In the past few years, two boat groundings have occurred within the park. Numerous moorings are maintained by the State of the Hawaii. These moorings have reduced anchor damage but are point locations for significant recreational impacts.
- Contaminants: Industrialization is rapidly occurring around the park and will have an effect on contaminants entering the marine environment. The presence of the marina within the park boundary is also a potential source of contaminants in the park, particularly metals and hydrocarbons. To date, however, little work has been done on the status of contaminants within the park. Baseline work on transport mechanisms (e.g. groundwater) is nearing completion.
- Disease: Coral disease is present in the park at very low levels, as in other areas of Hawaii.
- Fishing/Collecting: Net fishing is a common occurrence in the park. While the park is closed to aquarium fish collecting, limited enforcement by the state allows this practice to occur, especially from land-based collectors. Endemic limpet (opihi) collecting is not a significant problem now, primarily because their populations have been severely overcollected in the past and these limpets now occur only in low densities of small individuals.
- Groundwater: KAHO has a significant number of groundwater intrusions or springs along its coastline. These intrusions alter salinity and temperature, and can carry nutrients or other contaminants from upland sources. Species tolerant of changes in salinity and temperature may occur around these intrusion areas.

- Land Use/Development: The Kona coast of the island of Hawaii is experiencing rapid urbanization. Recent changes in zoning designations will allow for the expansion of an industrial complex immediately upland from KAHO. The NPS recently intervened successfully in related State of Hawaii Land Use Commission actions to effect positive controls on new development to minimize the potential release of contaminants into ground water that can enter the park and affect nearshore marine resources. Residential areas (sources of nutrients and contaminants) as well as a major road from the tourist center to the Kona airport border the park, as does an active marina to the south. Pressure to develop is high on the lands adjacent to KAHO.
- Landfill: A large landfill for the Kona side of the island lies downwind of the park. It is not believed to be a significant threat to park resources, but could present a minor problem to groundwater quality or be a minor source of solid waste.
- Litter: KAHO has a significant solid waste problem generated by visitors. Litter includes plastic bags and other picnic items that have been observed floating in the ocean. This type of litter is a significant potential threat to sea turtles that are known to consume these items.
- Marina: Honokohau Boat Harbor is the primary marina facility near the tourist center of Kailua-Kona. This marina has extensive use from charter sport fishing and other tour operators and local boaters. In addition to the usual marina impacts, this facility has no sewage pumping facility and boaters are expected to dump wastes outside of the three-mile limit. Compliance with this regulation is unknown. The marina has an unsupervised and heavily-used public boat wash facility that drains into nearshore waters. The lack of supervision does not ensure the use of low phosphate soaps or prevent the release of other contaminants.
- Marine Debris: Marine debris is present in the park but little is washed up on the beach. Trolling gear is the most commonly found entangled fishing equipment. Illegal mooring buoys are frequently found in park waters.
- SCUBA Diving: SCUBA diving is a popular tourist activity in Kona. Most dive vessels operate out of the adjacent Honokohau Boat Harbor and use numerous sites within the park. Impacts of high levels of SCUBA diving on park resources have not been documented, but SCUBA divers can have a profound negative impact on the coral reef ecosystem if appropriate care is not taken. Fish feeding is not practiced by the local dive operators.
- Seasonal Weather: KAHO experiences strong seasonal surf. High surf conditions occur predominately during winter months. Effects of seasonal weather on marine resources appear to be primarily restricted to these sea conditions. Rainfall is relatively low and fairly constant throughout the year.
- Sedimentation: Sedimentation onto nearshore habitats primarily occurs from fishponds. Otherwise, terrestrial sedimentation is a minor concern at KAHO.
- Sewage: Secondary treated sewage is injected into a lava tube near the park boundary. Presently, the fate of this sewage is unknown. Residential areas upslope of the park are

on cesspools. Animal waste is a problem along the beach, as visitors do not always clean up after their pets.

PUHO

- Alien and Invasive Species: Invasive and alien species are a persistent threat to all ecosystems in Hawaii. The park presently has no information on marine alien or invasive species in its coastal area
- Beach Activity: Beaches within the park are visitor attractions causing potential conflict with sea turtles. Currently the park keeps visitors away from areas where turtles are resting on the beaches. The public uses the beaches to swim, walk, and wade, but because of the cultural significance of the beaches, towels and sunbathing are restricted. Beach use is heightened because a popular public beach and snorkel site is adjacent to the park, and swimmers and snorkelers often enter the park via the ocean.
- Boating: A heavily used boat ramp is immediately adjacent to the park, resulting in considerable small vessel traffic and the potential for fuel or other contaminants spills. While the park has no submerged lands within its boundary, boating is a concern. Boats travel at high speed through the waters adjacent to the park and could be a hazard to turtles. They also generate considerable noise and air pollution that is disruptive to the park and its visitors. The effects of these impacts on animals using the coast are unknown. Boats are also a mode of transportation for people entering the park and, in spite of NPS efforts, some tour operators allow their customers to climb out of the water and onto the basalt cliffs that line the southern portion of the park, creating a potential safety hazard and possibly impacting biota.
- Contaminants: Strong evidence suggests that contaminants are present in the sediments of the anchialine pools at PUHO. If so, other sediment or soil contamination along the coastal zone is possible and needs to be investigated. The park has development upslope that could contribute to contaminant levels, including commercial coffee farms, livestock ranching, houses, highways, and parking lots. The park has historically used atrazine to control weeds and this persistent chemical may still be present in many areas of the park.
- Fishing/Collecting: Fishing and collecting of marine organisms is allowed within the park. It is currently unclear if fishing is restricted to native Hawaiians or open to the general public. Pole fishing and throw nets are the most common methods and fishing pressure is consistent but has not been quantified. The absence of endemic limpets (opihi) suggests that collecting pressure may be very high on these organisms. Limpets (opihi) are rare throughout the state primarily because of over collection.
- Groundwater: Another park (KAHO) on the Kona coast of the island of Hawaii has found significant groundwater contamination. No studies have examined groundwater at PUHO. Future residential development upland from the park could affect groundwater quantity and quality.
- Marine Debris: With high levels of fishing and boating in and around the park, marine debris has the potential to be a significant stressor. Levels and possible effects of marine debris have not been examined.

- Sewage: Housing upslope from the park uses septic tanks. The park has outdated infrastructure which requires the use of holding tanks and the operation of a lift station to remove its sewage waste. Either of these could be leaky and contribute to contamination, including potential nutrient input into groundwater or coastal waters, that could affect PUHO resources. The park also has a significant animal problem (feral cats and mongoose) that may be contributing to potential nutrient enrichment problems in the park. No work has been conducted at the park and the effects, if any, are unknown.

HAVO

- Alien and Invasive Species: Little is known about invasive species in coastal areas of the park. Inventories have not been completed. The potential for impact from invasive species is unknown.
- Boating: Boating is not a significant problem in the park. Boats may transport endemic limpet (opihi) pickers into remote areas. This is a common practice along the coasts of this and other Hawaiian islands and can lead to significant effects on opihi populations that are otherwise in remote, inaccessible areas.
- Fishing/Collecting: Fishing is allowed in the park, but for half of the park's coast, it is restricted to native Hawaiians. Fishing methods, however, are not restricted. Park staff believes fishing levels are relatively low, but no assessment has been made. Endemic limpets (opihi) are highly prized for local consumption, and opihi harvesting is most likely occurring in the park.

ALKA

- Alien and Invasive Species: Marine invasive species, while poorly understood relative to thei terrestrial counterparts, may have a profound detrimental effect on the ecosystem,. ALKA, as with many of the PACN parks lacks comprehensive marine surveys. While marine invasives are not believed to be a significant problem at this time, concrete data is lacking for this park.
- Boating and Marina: While the final boundaries for ALKA have yet to be determined, this park is certain to be adjacent to one or more small and/or commercial marinas. Boat traffic is also expected to be high. These issues, as discussed under the other Hawaii Parks (i.e. KAHO, PUHE, and PUHO), are also relevant for ALKA.
- Erosion and runoff: Increased urbanization (e.g., road construction, industrial activities, golf courses, residential cesspools) can contribute to erosion and runoff that could affect marine nearshore resources.
- Fishing/Collecting: Fishing and collecting of marine resources does occur within this park, but the magnitude and effect of this activity cannot be adequately assessed until the park's boundaries have been finalized.

Critical marine resources, and marine resources in general at most Pacific Islands I&M Network (PACN) parks are not known, primarily because of the lack of previous work and specialized scientific personnel at most parks. Where personnel exist, various types of assessments are in progress. The NPS Pacific Islands Coral Reef Program (PICRP) and (PACN) are new programs, and in-water work for monitoring protocol development, inventories and research is just beginning in earnest in some of the parks. For this report, critical resources were identified by consulting with park staff and other marine experts, reviewing relevant scientific and technical literature, and assessing available data sets. In most cases, in-water surveys of critical resources have not been conducted and thus the presence and status of some resources will need to be determined in the future. Table 1 summarizes these identified critical resources.

Table 1. Critical Resources found in PACN National Parks

Resource	AMME	HALE	HAVO	KAHO	KALA	NPSA	PUHE	PUHO	WAPA	USAR	ALKA
Mangrove wetlands	X					X					
Seagrass beds	X								X		
Extensive algae beds	X			X	X	X			X		X
Coral reefs	X			X	X	X		X	X		X
Tidepools		X	X	X	X		X	X	X		X
Beaches	X		X	X	X	X	X	X	X		X
Basalt cliffs & benches			X		X	X		X			X
Lava tubes			X	X							X
Sea turtles	X	X	X	X	X	X	X	X	X	X	X
Marine mammals	X	X	X	X	X	X	X	X	X	X	X
Seabirds & shorebirds	X	X	X	X	X	X		X	X		X
Reef fish	X			X	X	X	X	X	X	X	X
Endemic gobies		X			X	X					X
Endemic limpets (opihi)		X	X	X	X			X			X
Sharks							X				X
Endangered species	X	X	X	X	X	X	X	X	X	X	X
Offshore islets					X				X		
Submerged heiau							X				

The stressors on the marine environment at many PACN parks are poorly described. Table 2 summarizes known and suspected stressors on the marine environment as they may be present in each PACN park.

Table 2. Major stressors identified for PACN National Parks

Stressor/Threat	AMME	HALE	HAVO	KAHO	KALA	NPSA	PUHE	PUHO	WAPA	USAR
Invasive Species	X	X	X	X	X	X	X	X	X	X
Local Weather	X	X	X	X	X	X	X	X	X	X
Contaminants	X			X	X	X	X	X	X	X
Fishing/Collecting		X	X	X	X	X		X	X	

Boating	X		X	X	X		X	X	X	
Litter	X	X		X		X	X		X	X
Groundwater	X			X	X	X	X	X	?	
Land Use/Development	X	X		X		X	X		X	
Sewage	X			X	X	X		X	X	
Marine Debris		X		X	X			X	X	
Sedimentation				X		X	X		X	X
Season Weather		?	?	X	X	X	X	?	X	
Landfills	X			X	X	X				
Hurricane/Typhoon	X					X			X	
Marinas	X			X			X			
Disease	?	?	?	X	?	X	?	?	?	?
Runoff	X				?	?		?	X	?
Beach Activity				?			?	X	X	
Population Outbreaks	?					X			X	
SCUBA Diving	?			X					X	
Light	X								X	
Relic Military Equip.									X	X
Climate Change	?	?	?	?	?	X	?	?	?	?
Population Growth	?	?	?	?	?	X	?	?	?	?
Erosion	X									
Sand Mining						X				
Hazardous Gases										X
Bioprospecting				?	?	?	?		?	?
ENSO Events	?	?	?	?	?	?	?	?	?	?
Jet Skis	?								?	

MONITORING

Sampling design is a critical element that will determine the utility of, and ability to interpret monitoring data now and in the future. For each specific question, set of questions, or monitoring objectives, appropriate sampling designs must be employed to collect data and draw appropriate conclusions from monitoring results. Monitoring needs may vary by park and may necessitate different methodologies, however, different parts could be generic and should be adaptive. Ideally, sampling design for NPS marine monitoring at PACN parks needs to yield information across all Pacific Islands National Parks that is comparable over time, among parks, and whenever possible, incorporate data parameters that are being collected in surrounding areas and by other agencies. This is not to say a "one-size-fits-all" parks monitoring plan should be employed but the design should be broad enough to meet common information needs for resource management across the network, yet sufficiently flexible and adaptive to usefully apply to each park's unique local environments, conditions, and needs.

Moreover sampling design must be planned, undertaken, reviewed, and (as needed, carefully) adaptively modified over time such that sampling remains appropriate, and data remain comparable to follow past, present and future trends in the environment that must be understood for effective resource management. The role of the monitoring program should be such that it generates scientifically rigorous data on reef health that will warn managers of potential problems so that appropriate studies or actions can be designed and implemented to address these problems.

As sampling designs and protocols are developed, methodology examples will be drawn from organizations that have long-term established monitoring programs (Monitoring section A). Presently, methodologies for some monitoring protocols are being undertaken on studies of sedimentation in WAPA. Other areas that will be pursued include benthic monitoring, intertidal monitoring, indicator species monitoring, seagrass monitoring, algae monitoring and Threatened and Endangered species monitoring.

In order to effectively conduct and maintain a comprehensive, productive long-term marine monitoring program, each park needs to have access to specially trained personnel, specialized equipment, and facilities. Parks need marine biologists with knowledge, experience (specialized taxonomic, working marine field, and data handling and analysis), interest, and focus in tropical marine sciences. Temperate marine biologists would require significant time to acclimate to the special working conditions and requirements in the tropical Pacific. Terrestrial ecologists, without extensive additional training, do not have the knowledge, skills, or experience required to implement and sustain a marine monitoring or research program.

Fielding and sustaining a long-term marine monitoring program will require access to highly specialized, experienced and skilled scientist-SCUBA divers with experience conducting complex subtidal research and monitoring tasks in difficult underwater environments. This training is expensive and requires yearly refreshers. Specialized equipment includes SCUBA equipment, boats with safety gear, and marine instrumentation. Specialized facilities include wet lab space for chemical and biological work that can accommodate seawater. These highly specialized and experienced personnel are being continually trained by academic institutions in the tropical Pacific, and a qualified pool is available with proper planning.

Needs that cannot be handled by in-park staff can be contracted out to qualified individuals, most likely associated with a university or government agency. However, because of the specialized nature of this work, costs for contracting these services are extremely high. Contracting an entire marine program is not feasible for this reason, and because there is a need for consistency in data collection over the long time duration required for marine monitoring.

The following section first outlines established programs that are available for the PACN to draw upon from known and recognized methodologies. These are followed by detailed summaries of past and current monitoring programs that have occurred within or adjacent by park. A brief description of inventories for each park is also listed to show what type of baseline information is currently available. These programs not only provide examples of methodologies, they also outline potential partners and collaborators. In addition, monitoring issues, needs and priorities are addressed for each park.

ESTABLISHED MONITORING PROGRAMS

International

- AIMS Long-term Monitoring Program: The Australian Institute of Marine Sciences (AIMS) has been conducting coral reef monitoring on the Great Barrier Reef since 1985. Crown-of-thorns seastar surveys have been conducted since 1985 and data on fish and coral communities have been collected since 1992. These data have been collected to support management by the Great Barrier Reef Marine Park Authority of coral reefs.

From this work, AIMS has developed a monitoring methods manual that is now available.

- Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program: The AGRRA monitoring program is an international collaboration of scientists and managers aimed at determining the condition of Caribbean reefs. This program examines the conditions of reef-building corals, algae and fishes at over 25 sites around the Caribbean. Methods employed by this program are available on-line and can be found at: http://www.coral.noaa.gov/agra/method/methodhome.htm
- Caribbean Coastal Marine Productivity Network (CARICOMP): CARICOMP was started in 1992 and collects data on the biodiversity of coral reefs, seagrasses and mangroves in the Caribbean. The program is based out of the University of the West Indies in Jamaica and involves marine laboratories in 15 countries. A CARICOMP methods manual which details methods for mapping and monitoring of physical and biological parameters is available at: http://www.ccdc.org.jm/methods_manual.html
- Global Coral Reef Monitoring Network (GCRMN): The GCRMN, an operational unit of the International Coral Reef Initiative, was established as a coordinating organization to assist governments, institutes, and NGOs in establishing monitoring programs by creating and publishing methods, to help regional monitoring programs (e.g. AGRRA, CARICOMP) publish results, and to raise public awareness as to the status of coral reefs. GCRMN advises on, but does not actively conduct any coral reef monitoring.

Federal

- EPA : The US EPA conducts or mandates discharge agencies to perform environmental monitoring of sewage outfalls throughout the US and its territories. This monitoring program comprises water quality, benthic communities and contaminants. Some of the biomonitoring generates data valuable for coral reefs. In some instances, coral and fish communities are also assessed. Some outfalls are at diving depths and monitoring of these yields scientifically rigorous data. Some monitoring has occurred for 20 years or more.
  The U.S. EPA is in the process of implementing its R-MAP program. R-MAP is designed to monitor reef health over an island-wide scale and will employ similar biomonitoring methods but using a randomized sampling design for rigorous statistical analyses.

- Florida Keys National Marine Sanctuary Water Quality Protection Program (EPA & NOAA): This water quality monitoring program was the first of its kind developed for the marine sanctuary systems. The goals of this program were to obtain recommendations for corrective actions, conduct monitoring, conduct research, and provide public education/outreach. These activities are collaboratively conducted by the EPA, NOAA, and the Florida Department of Environmental Protection (FDEP). This program funds three long term monitoring projects including overall water quality, coral reef and hardbottom community health (Jaap et al. 2003) and seagrass community health (Fourquearean et al. 2003). More information can be found at: http://www.fknms.nos.noaa.gov/wqpp/welcome.html

- NPS, Virgin Islands National Park: Virgin Islands National Park, in cooperation with Dr. Caroline Rogers of the US Geological Survey, Biological Resources Division, Virgin Islands Field Station has been conducting coral reef monitoring for over 10 years. This program has pioneered many techniques for monitoring most aspects of the coral reef environment off St. John's USVI, and has published a comprehensive monitoring methods manual available at: http://cars.er.usgs.gov/Coral_Reef_Ecology/Coral_Monitoring_Kit/coral_monitoring_kit.html.
- NOAA Center for Coastal Monitoring and Assessment Biogeography Program goal is to "is to develop knowledge and products on living marine resource distributions and ecology throughout the Nation's estuarine, coastal and marine environments, and to provide managers and scientists with an improved ecosystem basis for making decisions." They develop tools and applications to interpret relationships of species and their surrounding environment such as habitat mapping of coral reef ecosystems and designing and evaluating Marine Protected Areas. They have recently completed benthic habitat maps of the Main Hawaiian Islands. Information on their program can be found at: http://biogeo.nos.noaa.gov/.
- Fish and Wildlife Service, Honolulu Office: The USFWS Honolulu Office conducts limited coral reef monitoring throughout US island possessions in the Pacific, including the NW Hawaiian Islands Coral Reef Ecosystem Reserve. Monitoring is restricted in most places to coral population estimates (e.g. species diversity, percent cover), and growth. This monitoring effort is relatively new and is being conducted by Dr. James Maragos.
- Hawaiian Islands Humpback Whale National Marine Sanctuary Ocean Count: Hawaiian Islands Humpback Whale Marine Sanctuary Ocean Count started in February of 1996 on Oahu, with the Island of Hawaii added in 1999, Kauai in 2000, and Kahoolawe in 2002. The project covers 60 sites on these islands with over 2000 volunteers counting the number of whales observed in a four-hour period. Site locations on the Island of Hawaii along the proposed ALKA corridor include Upolu Point, Old Coast Guard Road, Kapaa Beach Park, Lapakahi State Park, Puukohola Heiau, Mile Marker 7, Hualalai Four Seasons, Keahole Point, Keahou Lookout, Honaunau Lookout, Hookena Beach Park, Milolii Lookout, Punaluu Beach Park, Kaena Point and Kahena Lookout. The most recent report found that approximately 5000 whales winter in Hawaiian waters. They also found no significant difference in trends from 2002 to 2003, that humpback whales are more abundant in February, and that they are also more abundant on the Island of Hawaii (Maldini 2003). More information can be found at: http://hawaiihumpbackwhale.noaa.gov/volunteer_program/ocean_count.html

State/Territorial

- Common Wealth of the Northern Mariana Islands (CMNI): A CNMI Inter-Agency Marine Monitoring Team (MMT) comprised of biologists from several CNMI government agencies conducts extensive coral reef monitoring throughout the Northern Mariana Islands. This program is relatively new (est. 1997), but the agencies and personnel involved hope to make this a long-term effort. The basis of this program is to evaluate the health of waterbodies by measuring and monitoring benthic communities. Methods are available in numerous technical reports. These methods are available online at: http://www.deq.gov.mp/MMT/Marinehome.htm

- Hawaii Coral Reef Assessment and Monitoring Program (CRAMP): The CRAMP program was supported by NOAA through the Hawaii Coral Reef Initiative Research Program. CRAMP originated in 1997 at the University of Hawaii in cooperation with state government agencies to develop a statewide network of long-term coral reef monitoring sites. CRAMP has developed standardized coral reef assessment and monitoring methods that provide scientifically rigorous biological data for corals and fishes but not other ecosystem components, including other invertebrates and algae. Transects are at 3 and 9 meter (10 and 30 feet) depths, which does not encompass extensive areas of reef development below these depths. These methods are available on-line: http://cramp.wcc.hawaii.edu/Overview/3._Methods/

- West Hawaii Aquarium Project (WHAP): WHAP, since 1998, has been studying aquarium fish in 23 sites along the West Hawaii coast to analyze the impacts of aquarium fish collecting and the effectiveness of Marine Protected Areas (MPA) and Fish Replenishment Areas (FRA). This study aims to 1) estimate impacts of aquarium fish collecting in West Hawaii, 2) evaluate effectiveness of the FRA plan to increase aquarium fisheries, 3) estimate critical habitat characteristics for adult and juvenile aquarium fishes, and 4) document recruitment patterns of aquarium fishes. Surveys began in March 1999 and are conducted on a bimonthly basis. Data collected include fish densities, recruitment patterns, coral cover, abundance, diversity, distribution, and rugosity. Sites are located at the following locations: Lapakahi, Kamilo, Waiakailio Bay, Puako, Anaehoomalu, Keawaiki, Kaupulehu, Makalawena, Wawaloli Beach (KAHO), Wawaloli (KAHO), Honokohau (KAHO), Papawai, S. Oneo Bay, N. Keahou, Kualanui Point, Red Hill, Keopuka, Kealakekua Bay, Keei, Hookena – Kalahiki, Hookena – Auau, Milolii – Omokaa, and Milolii – Manuka. More information can be found at: http://coralreefnetwork.com/kona/

Universities

- Quest: The University of Hawaii, the Kalakaua Marine Education Center: This program monitors seaweeds, coral, non-coral invertebrates and fishes at Puako on the West Hawaii coast using SCUBA techniques. This program is a part of the Marine Option Program at the UH University system. Surveys are annual since 1992 in the month of May. More information can be found at: http://www.coralreefnetwork.com/research/monitor/hawaii/puako.htm

Non-Government Organizations (NGO)

- Reef Check: Reef Check is a program of the Institute of the Environment at the University of California Los Angeles that uses volunteer divers and snorkelers in over 50 countries to collect data on coral reef health throughout the world. While there are limitations on the scope and quality of data collected it can be argued that for many reefs where no information exists, some information is better than none. Methods used by

Reef Check are available on-line at:
http://www.reefcheck.org/participate/manual/instruction_manual_03%20.pdf

PARK INVENTORIES AND MONITORING

WAPA

Inventories: Randall and Holomon (1974) conducted a coastal assessment of Guam's shoreline from the 60 foot contour depth to the first major landform change after the beach area. Included in this study was a description of the structural elements of the following: major vegetation zones, rivers, estuaries, bays, beaches, rocky coastlines, reef zones, water masses and circulation patterns, climatic zones, geology and soil types, development areas and use patterns, and areas with rare or unique animals and plants.

The Army Corps of Engineers (1980) conducted a shoreline inventory of Guam describing physical characteristics, emphasizing shoreline erosion problems. They describe the physical characteristics of the shoreline and backshore area, qualitative analysis of coastal processes, and descriptions of fringing reef characteristics.

The University of Guam Marine Laboratory, for the Guam Coastal Management Program conducted baseline studies on mapping Guam's coastal region, mapping beaching, rocky shorelines, mangroves, river estuaries, and general distribution of corals, seagrasses, and sediments on reef-flat platforms (Randall and Eldredge 1976, Wilder 1976). Randall (1978) conducted more regionalized studies with baseline information for Fouha, Agat, Agana and Tumon Bays. They collected data on the quantitative distribution and community structure of benthic organisms, including coral, algae and macroinvertebrates.

The Agat Unit was a part of an environmental impact study of Agat Bay during 1975-76 by the University of Guam Marine Laboratory (Eldredge et al. 1977). The survey included a catalog of marine organisms at Agat Bay, ocean current study and potential impact from development. Cataloging included studies conducted on invertebrates (Eldredge 1977), corals (Randall 1977), gastropods and bivalves (Dickinson and Moras 1977), opisthobrancs (Carlson and Hoff 1977), fish (Gawel 1977), and marine plants (Tsuda 1977).

In part of an effort to gather baseline information on Guam's reef biological communities, the Office of Coastal Zone Management contracted the University of Guam to conduct studies on biological communities. Amesbury (1978) conducted a study on the nearshore fishes on species composition, abundance, distribution and environmental factor influencing these. Transect locations included two in Tumon Bay, two in East Agana Bay; both north of the Asan Unit. On the East coast side 4 transects were in Fouha Bay. And on the southwest coast 2 in Ylig Bay. Of the two sites that were located in Agat Bay, one was immediately within park boundaries (at the cemetery) and the other was at Rizal Beach just immediately on the north end of the Agat Boundary. For the transect located within the park boundary, there were 21 species observed on the inner reef flat and 14 observed on the outer reef flat during a survey May 24, 1977. A later survey on December 15, 1977 yielded less species observed 15 and 3 for inner and outer reef flats, respectively.

Also, as a part of the biological study of Guam's reef community, Randall, ed. (1978) contributed baseline information on marine plants, corals, and other macroinvertebrates. Surveys were conducted in the same bay locations. For marine plants, both species composition and percent cover was obtained at two times of the year. The number of species of marine plants observed in the site located within the park at Agat Bay was 38 (46 for the Bay). Coral distribution, size distribution, growth form distribution, and vertical profiles were found for two transects within the park at Gaan Pt. and just north of the Togcha River. Macroinvertebrates were also surveyed at the same locations as the coral, and in transects located within the Agat Unit, 12 species were observed.

Eldredge (1979) compiled information on both the Agat and Asan units, with information on the physiography, biotic resources, and recreation activity in a report to the National Park Service. Information on the Agat unit was drawn from Eldredge et al. (1977). Information for the Asan unit was drawn from Chernin et al. (1977) and from known observations.

WAPA has adequate baseline inventories for fish within the park. WAPA has initial inventories for algae, corals, and macro-invertebrates, but they are not complete. Additional information can be gleaned from University of Guam Marine Laboratory, and other technical reports, but accurate baseline inventories are still be needed for marine invertebrates including corals, algae, and vascular plants. Funding has been obtained for an algal inventory to be started in FY05. A comprehensive inventory of the sand beach community in the park is needed.

Gawel (1977) conducted an inventory of fish species in Guam, including locations within the Agat Unit. Amesbury (1999) conducted a biological survey of both the Agat and Asan units, including a survey of marine fish. He found a total of 193 species in both units. Park staff continually update species lists and the most recent database has 255 known species for the park (WAPA Natural Resource Management).

Portions of the Agat Unit were included with comprehensive invertebrate surveys (with separate macroinvertebrate and coral surveys) of Guam's coral reefs conducted by the University of Guam Marine Laboratory (see Randall 1978, Eldredge et al. 1977 below). More recently, Amesbury (1999) conducted a biological survey of both marine units, finding 191 species of macroinvertebrates and 57 species of coral.

Tsuda (1977) surveyed part of the Agat unit in a study on benthic algae. Amesbury (1999) conducted a biological survey of the Agat and Asan units, including a study on algae. He documented a total of 34 species of marine plants. *Amphiroa*, *Haalimeda*, *Neomeris*, and *Padina* were the most commonly observed algal species present, covering up to 75% of the available area. The distribution of seagrass and invasive marine algae by University of Hawaii and WAPA NPS ecologists is scheduled for FY05.

Additionally, an invertebrate survey was completed for the Piti Bay Underwater Observatory (just outside the park). The US Navy conducted PCB work just inside and adjacent to the Agat beach Unit.

Past & Current Monitoring: Monitoring of natural resources in WAPA is almost non-existent. Currently, the park is establishing base line condition s for sedimentation, temperature, coral recruitment rates and other biological parameters (e.g. percent cover). NPS and the University of Guam are conducting baseline studies to document sedimentation (rates and composition) on the island's coral reefs. Other data currently collected includes water temperature and Photosynthetically Active Radiation (PAR). Studies on coral recruitment and percent cover are underway.

Along with the University of Guam, WAPA is monitoring erosion rates in burned and non-burned plots. They are trying to gain a better understanding of the effects of wildfire on tropical savannah grasslands so the park can establish best management practices for reducing erosion. This monitoring program addresses some of the land-based effects on coral reefs and is paired with the above monitoring program on sedimentation.

Development of monitoring protocol for seagrass and assessment of alien algae will commence August 2005 by the University of Hawaii and NPS ecologists.

The Government of Guam Department of Agriculture, Division of Aquatic and Wildlife Resources (DAWR) is conducting fisheries stock assessment surveys to determine the effects of marine preserves on fish populations. The Asan fore reef slope (in the park) serves as a control site for the study. This study site overlaps with two of the sediment monitoring sites.

Adjacent Monitoring: The University of Guam, Water and Energy Resources Institute (WERI – http://www.uog.edu/weri) monitors surface and ground water quality, pesticide and heavy metal contamination, and soil runoff. They also analyze duplicate samples from the Navy's remediation program for the Orote Peninsula.

Guam Environmental Protection Agency (GEPA – http://www.guamepa.govguam.net/programs/index.html), as a part of its Monitoring Strategy for the Territory of Guam monitors *Enterococci* weekly at recreational beaches and surface water regularly. Three sample locations are adjacent to WAPA units. One site is just north of the Asan Unit and the other two are to the North and South of the Agat Unit.

Surface water monitoring occurs near streams and bays and includes the following "conventionals": pH, total suspended solids, total dissolved solids, temperature, turbidity, Nitrite-nitrogen, dissolved oxygen, salinity, total phosphorus, and ortho-phosphorus.

Additionally, GEPA is developing a biological monitoring program "Feshwater Periphyton and Benthic Macroinvertebrates Assessment Program." They assess the periphyton and benthic macroinvertebrate freshwater assemblages and assess the levels of major chemicals of potential environmental concern (CPEC) in both sediment and tissue samples of recreational, commercial, and subsistence target species.

Navy Environment monitors water quality at 11 wells with the closest sites located near the Naval Hospital as well as the Almagosa Springs.

The area south of the Orote Peninsula is monitored by the US Navy as part of remediation for the Orote dump. This monitoring program includes analysis of water, invertebrates and fish for PCBs, heavy metals, dioxins, ferro-cyanins, and chlorinated pesticides. The area is currently open to recreational swimming but is closed for fishing.

DAWR is trying to determine Guam's sea turtle nesting populations and determine sea turtle nesting habitat type. They are using satellite telemetry as well as monitoring known nesting beaches.

Monitoring Issues: WAPA currently has the personnel, equipment, and facilities required to run most components of a comprehensive marine monitoring program. Currently, through NPS coral reef funding, WAPA has three qualified, SCUBA certified, marine scientists on staff. WAPA has SCUBA equipment, a boat, most sampling gear, and access to a field biology laboratory equipped to handle seawater. WAPA is in the process of starting pilot monitoring sites to test a variety of protocols for monitoring and their appropriateness for reefs in the park.

Needs and Priorities: WAPA is lacking recent, formal inventories for many of its natural resources, and in particular for marine invertebrates, marine algae, and invasive species. There has been very limited work conducted on marine algae in Guam and recent inventories are needed, particularly with the potential for invasion by alien species and based on their resulting impact on Hawaiian nearshore reefs and beaches. A baseline inventory of marine invertebrates is also needed. Focal fish species are not well known for in the marine environment at Agat and Asan, and should be studied further to determine species to monitor. Continued and additional water quality monitoring is important for both marine and freshwater resources.

AMME

Inventories: While there may not be surveys that occurred in the park, there are several past studies within the vicinity of the Managaha Lagoon that might be applicable to the park.

The Managaha Patch Reef site (located directly offshore from the park) was surveyed for benthic cover and coral communities before and after the Saipan Channel dredging project (University of Guam). A recent checklist for all coral and fish species encountered during CNMI Inter-Agency Monitoring Team (MMT) is also available (Houk 2001). Turf algae was the predominant benthic species observed with the next being corals, the dominant corals including *Montipora spp*. and *Porites spp*. Acanthurids and Scarids (Surgeonfishes and Parrotfishes) were the most abundant fish species. These results were similar to a previous study (Birkeland et al. 1997). Data also collected in this last survey include percent cover, coral colony diameter, water quality and sedimentation rates.

Observations and measurements of coral were made to determine coral density, dominance of substrate of living corals, and frequency of occurrence (Gawel 1974). Coral damage was assessed and water flow was studied in the Tanapag Barrier (Randall 1987). Coral reef areas have been summarized by Hunter (1995) and NOAA (http://state_of_coast.noaa.gov/bulletins/html/crf_08/crf.html). Mapping and monitoring of US coral reef ecosystems is also being done (http://biogeo.nos.noaa.gov/projects/mapping/pacific/territories/data/ accessed 9/8/2004).

Another several sites (including Range Light Bay, Echo Bay, Charlie Bay, Baker Dock, Baker Bay, Able Dock, Iron Pilings and Unai Sadog Tase) just north of the park in Tanapag Harbor served as a study site for a power barge impedance study (Doty and Marsh 1977). Included in this environmental assessment were assessments of sediment descriptions, water motion and temperature, oxygen and nutrients, marine plants, corals, mollusks and invertebrates, zooplankton and fishes.

Kolinski et al. (2001) tried to get a count of green sea turtles on Saipan and estimated there to be 169 green sea turtles to be in the vicinity of the island. They found many of these sightings on or near uninhabited coast lines. They found sea turtles to be foraging on two species of seagrass and 29 species of algae.

Marine surveys in other areas of Saipan include those for creel (CNMI Division of Fish and Wildlife 1988 and 1993), coconut crabs (*Birgus latro*) (Amesbury 1980), marine plants (Fitzgerald and Tobias 1974), fishes (Trianni 1999, Houk 2001), fish and spawning areas

(Amesbury et al. 1979), crown of thorns starfish (*Acanthaster planci)* (Goreau 1969 and 1972), collector urchin (*Tripneustes gratilla*) (Cloud et al. 1959), sea cucumbers (Chandran 1988, Tsuda 1996), seagrasses (Tsuda et al. 1977), and agar-agar (Nelson et al. 1982).

Coastal Resource Management (CRM) and Department of Environmental Quality (DEQ) marine biologists conducted a habitat survey of the lagoon's southern half to understand potential sea urchin habitats, and collector urchin populations in these waters (Yuknavage 2001). An underwater survey was conducted in June 1986 of lagoon waters adjacent to the Puerto Rico Dump to determine the nature of the biological communities (Richmond and Matson 1986); this study found that the marine community adjacent to the dump is "normal" although the area southwest of the dump had high coral mortality. Ocean currents, vegetation, and wildlife were measured in 1987 in preparation for rehabilitation of the Smiling Cove Marina. Channel, inner basin, and reef-flat areas were surveyed, and checklists and relative abundances were recorded for marine plants, corals, and fishes (PBEC 1987). Habitat and their correlations to fish were studied around Managaha Island (Tenorio 1999). From 1984 through 1988, the Division of Fish and Wildlife (DFW) conducted regular reef fish surveys to track changes in abundance and diversity (CNMI DFW 1988). A species checklist is maintained by the DFW (1994). Reef fish abundance were also sampled near AMME in the Managaha Marine Conservation Area (Trianni 2003). Studies of the power barge Impedence included marine plants (Tobias 1977), corals (Doty et al. 1977), mollusca and other benthic invertebrates (Dickinson 1977), zooplankton (Amesbury and Doty 1977), and fishes (Amesbury et al. 1977).

Past & Current Monitoring: The NPS is not currently conducting marine research within the park. Local government agencies are conducting little research in the area.

Adjacent Monitoring: The CNMI Inter-Agency Monitoring Team (MMT), CRM/DEQ/DFW is monitoring 9 sites, one of which includes the Managaha Reef, offshore from the park (Houk 2001, Bearden et al. 2004). These sites were selected based on their potential disturbances and sources of stress for coral reefs. They are monitoring benthic coverage, coral communities, fish abundance and macroinvertebrate abundance, biodiversity of corals & fish, sedimentation rates and water quality parameters.

DFW is also looking at no-take Marine Protected Areas and the effectiveness of 'spillover' effects of MPAs (Trianni 2003). The closest site to AMME includes the Managaha Marine Conservation Area.

The Commercial Purchase Survey collects commercial fisheries data on pelagic species, various invertebrates, and both shallow- and deepwater bottomfish which are marketed in Saipan (Micronesian Environmental Services 1997).

Monitoring Issues: With the exception of a small swamp, AMME does not have any submerged marine resources within its boundary and will not require specialized marine staff at this time. AMME does not have the equipment or facilities to run a marine monitoring program. WAPA has no natural resources personnel stationed at AMME, but supporting marine resource personnel exist at WAPA. The government of the CNMI is actively monitoring their nearshore marine ecosystems, and has the expertise, equipment and facilities to conduct this work. A cooperative agreement between the NPS and the appropriate CNMI agencies may provide this park with the needed equipment and facilities to conduct the research in cooperation with the coral reef program staff at WAPA.

Needs and Priorities: AMME has completed or is in the process of completing several primary surveys of marine resources within its boundary. A project to map and inventory the mangroves and wetlands within the park was completed in 2003 and a report should be forthcoming. This project inventoried plants and large terrestrial vertebrate animals living in the wetland. A survey of strand vegetation and animals should also be completed for the park. A comprehensive inventory of marine plants and animals is needed for these areas and a survey of terrestrial invertebrates needs to be completed.

NPSA

Inventories: An inventory of the coral (85 taxa) and fish (192 species) was conducted for the Tutuila park unit (Green and Hunter 1998). Wass (1984) inventoried fish throughout the territory, finding 991 species of fish. Because of the relatively small size of the territory, cumulative inventory efforts are considered to be an accurate fish inventory for the park. The most recent inventories of fish by Green (2002) identified fish to genus and species as well as minimum adult size. NPSA maintains online pictures of locally observed fish species (www.nps.gov/npsa/).

Corals were inventoried in Ofu Lagoon in 2002, when a limited inventory of other invertebrates and algae was also conducted.

A field survey utilizing qualified taxonomic specialists for alien and invasive marine invertebrates and algae was done in 2002 at several sites throughout the park and territory (Coles et al. 2003). They found few introduced species in marine waters surrounding Tutuila and if any in the park units.

These efforts and planned systematic inventories of marine invertebrates and algae in park waters should provide a thorough marine biotic inventory that meets NPS I&M program standards.

Past & Current Monitoring: A monitoring program assessing the health of the coral reef environment is currently being developed. Other territorial or federal agencies are conducting ongoing monitoring programs that have at least one monitoring site within the park's boundaries include a quantitative inventory of fish, corals, and selected macro-invertebrates , including distributions, densities, and condition of species (Green 2002, Fisk and Birkeland 2002).

Currently, NPSA is conducting a detailed study of fisheries effort and is developing protocols for monitoring methods. Coastal water temperatures are monitored at several locations within the park. Some on going coral work, through the USGS Hawaii Cooperative Fisheries Research Unit, University of Hawaii, is examining effects of climate change on corals in Ofu Lagoon. A survey of coral diseases has been done by USGS/BRD.

Adjacent Monitoring: DMWR monitors and assesses trends in annual fish harvests and invertebrates. They began monitoring pelagic and bottomfish in 1982, but monitoring of other artisanal and subsistence fisheries has been sporadic. Though the inventories are not conducted within park boundaries, it is an informative summary for the territory.

Long term monitoring of the coral reef community at Fagatele Bay (Birkeland et al. 2004) includes coral identification, percent cover and fish abundance by species. Between 1998 and 2001 an overall improvement was observed for corals whereas fish abundance declined.

NOAA has been creating sea surface temperature maps to be used as early warning indicators for coral bleaching. Additionally, NOAA has been monitoring water temperature, currents, and conducting coral and fish surveys in 2002 and 2004. They plan to update these surveys every two years.

Monitoring Issues: NPSA currently has the staff, equipment and limited facilities to conduct the basic components of a marine research and monitoring program. The park has made significant headway in developing a marine program. They have initiated monitoring the subsistence fishery within the Ofu-Olosega park unit and are actively developing protocols for reef fish monitoring applicable to reefs at NPSA. NPSA has a budget dedicated to marine resource management via the Coral Reef Initiative. NPSA faces a challenge not present at other parks: park units are spread over four separate and remote islands. To successfully work in all units, redundant facilities and some redundant equipment will be needed on all islands. At present, the Tutuila Unit is the primary focus of the staff. Some equipment and facilities are available at Ofu Island. Nothing is presently available on Tau or Olosega islands.

Needs & Priorities: NPSA currently has an incomplete inventory of marine mammals. Inventories of marine and terrestrial invertebrates are needed in all park units. Existing inventories of marine fishes and coral will be updated as new studies are conducted.

USAR

Inventories: In a survey of the “biofouling”, sedimentation and corrosion of the USS Arizona, Henderson (1986) created a checklist of common organisms observed on or around the hull of the sunken vessel. He found 25 taxa of encrusting organisms and 25 species of fish. Particularly abundant were sponges, *Schizoporella errata*, Annelids (*Branchiomma cingulata*., large Sabellids and *Salmacina* spp.), mollusks (Vermetids and oysters), both solitary and colonial tunicates, and filamentous red and green algae as well as diatom mats. No hard coral species were observed. Photo slides were taken with the idea that they may be used in future biological monitoring studies.

The first comprehensive biological inventories of marine benthos in Pearl Harbor were conducted by the Navy Undersea Center during 1970-1972 (Evans 1974). A shoreward piling approximately 91 meters from the USS Arizona Memorial was included in their study. This site is representative of the vicinity of the memorial, characterized as having vertical substrate with rocks, mud ledge and debris in its vicinity along with sand, mud and silt bottom approximately 9 meters below the surface. Included in this study were fish surveys, micro mollusk surveys, piling surveys of marine organisms on vertical surfaces and benthic surveys. Other data collected during this study included physical and chemical measurements of sediment, water quality, tidal movement, and runoff measurements.

A total of 388 taxa were observed in Pearl Harbor during these studies; including 23 species of algae, 278 species of invertebrates and 87 species of fish. In the benthic surveys 114 taxa were identified. Sediment samples of micromolluscs resulted in 37 species identified with *Hiatella hawaiensis*, *Odostmia oodes* and *O. indica* and *Crepidula aculeate* being the most widely distributed within Pearl Harbor. A total of 88 genera and 113 taxa were identified in the piling surveys that were conducted at two depths (0 and 3 meters). Commonly observed species/families in Pearl Harbor included: *Hiatella hawaiiensis*, *Syllidae*, *Cirratulidae*, *Crepidula aculeate*, *Pilumnus oahuensis*, *Styela* sp., *Vermetidae*, *Elasmopus rapax*, *Balanus amphitrite*, *Ophiactis savignyi*, and *Bugula* spp.

The study site (piling ~91 meters) closest to the USS Arizona Memorial site had 30 species identified with a mean of 185 individuals per sample. The predominant algae observed at the piling near the USS Arizona was *Caulerpa verticillata* while polychaetes and decapods were the faunal organisms most commonly observed. The USS Arizona site was described as having "very soft mud with Vermetid tube debris."

The Bishop Museum recently conducted comprehensive marine, freshwater, and estuarine invertebrate inventories for Pearl Harbor. In these reports, Englund et al. (2000) and Coles et al. (1997) provide background and historical documentation of environmental changes and biological studies occurring throughout Pearl Harbor. The survey sites in the 1996 Bishop survey (Coles et al. 1997) included the same stations surveyed by Evans (1974) during the 1970s. These sites included a station adjacent to the USS Arizona memorial and one at the northeast part of Ford Island.

Coles et al (1997) observed a total of 419 species found throughout Pearl Harbor, including 36 species of algae, 1 spermatophyte, 323 invertebrates and 59 fish species. This most recent inventory, included with past surveys give a total of 1123 taxa for Pearl Harbor (Coles et al. 1997). A significant observation in this study was that, of the species observed, 95 were either introduced or cryptogenic. Another significant finding of this study is that while 5 species of hard corals were documented at 8 sites in Pearl Harbor (Coles 1997); there were no hard coral species documented in the Evans (1974) study. The most commonly observed coral was *Leptastrea pupurea*, which also occurred at the northeast end of Ford Island. *Pocillopora damicornis* was found near the Navy Shipyard, on the opposite shore of the memorial (Coles 1999). It is thought that pollution control, a reduction in non-point source runoff contribute to more favorable conditions in water quality that allow for more sensitive species such as hard corals.

In a survey of the biofouling, sedimentation and corrosion of the USS Arizona, Henderson (1986) created a checklist of common organisms observed on or around the hull of the sunken vessel. He found 25 taxa of encrusting organisms and 25 species of fish. Photo slides were taken with the idea that they may be used in future biological monitoring studies. Additional work is required for USAR to produce comprehensive inventories of marine invertebrates, algae and fish. While no formal surveys of marine mammals and sea turtles have been conducted, reliable incidental visual observations have been made.

While no formal surveys of marine mammals and sea turtles have been conducted, reliable incidental visual observations have been made.

Past & Current Monitoring: The USS Arizona contains several hundred thousand gallons of fuel oil. Currently studies are being undertaken by the Submerged Cultural Resources Unit (NPS) that are examining how natural processes affect the structure and integrity of the sunken ship and the integrity of the hull is being monitored (Russell and Murphy 2004). Baseline environmental data are being collected from instruments placed on the USS Arizona. Data being collected include wind, wave and current patterns as well as pH, temperature, salinity, dissolved oxygen, oxygen reduction potential and conductivity. These baseline data will help to understand and characterize the nature and rate of natural processes affecting hull deterioration and the program is expected to collect 12 to 15 months of data. The corrosion process is being measured *In Situ* using pH and corrosion and by x-ray diffraction and scanning electron microscope using samples collected from different locations along the sunken vessel. Mathematical modeling of the hull life is presently being conducted. The possibility of using microorganisms in fuel oil degradation is being examined. Samples of oil, sediment, water & concretion are all being collected as a part of this study. GPS points are being taken for movement detection. GIS development via photographs & maps are also being developed. Furthermore, USAR staff regularly inspects the hull for signs of oil seepage.

Adjacent Monitoring: Pearl Harbor Watershed Environmental Restoration Projects contracted water quality studies by Leeward Community College (LCC) from April 18, 2000 - December 31, 2001. From 1979 to 1994, LCC students of Donald G. Klim studied water quality parameters at different locations throughout Pearl Harbor from Waiawa stream to West Loch.

Brock (1994, 1995) monitored fish and epibenthic fouling organisms on or near Hawaii Electric Company Waiau discharge on the West side of Ford Island and at the head of Aiea Bay.

The Navy Environmental program monitors water quality at the outfall from the Fort Kamehameha Wastewater Treatment Facility for temperature, ammonia, nitrate/nitrite, totally nitrogen, total phosphorus, turbidity, chlorophyll a, salinity, dissolved oxygen and pH. After qualifying rainfall events, storm water run-off is monitored at eight sites around the Pearl Harbor Naval Base.

Monitoring Issues: Due to the nature of its resources, USAR has no expressed or mandated need for marine biological monitoring. USAR has no trained staff to conduct a marine monitoring program, however, the park does have an active dive program. Equipment and facilities to support diving are available but specialized scientific facilities and equipment are not. USAR, however, is close to the PICRP science advisor, other staff, equipment and facilities at the University of Hawaii, which are all available to help support park needs.

Needs and Priorities: A priority for natural resource inventories would be to complete comprehensive and updated inventories of invertebrates, algae and fish present at USAR. The only study within USAR that provides a partial checklist for a park inventory list was conducted by Henderson (1986) that included only major species present that were readily identifiable; and did not identify rare, microscopic or cryptic organisms. Some of the species included in the checklist were identified to genus.

Invertebrate and algal community structure are a priority for natural resource monitoring, particularly because of their role in assisting with structural rigidity of the hull. The presence of invasive species, as their effect on the present community structure is not known. If these species persist, they could affect community structure and potentially disturb the organisms that have been incorporated into the hull.

Continued and more in depth water quality monitoring is needed for this park. Water quality is an important facet in both biological and structural facets.

HALE

Inventories: Hawaiian goby inventories have been conducted, and their distributions in park streams have been mapped. No marine inventories have been completed for HALE. As a result, we include adjacent studies that could provide some idea of probable resources in the marine areas of HALE.

Bass and Teshima (1985) conducted a baseline marine survey at Ahihi Bay as a part of the Marine Option Program through the University of Hilo and found percent cover values for the subtidal substrate of: 51.6% limestone rubble, 9.9% sand, 25.8% corals and 14.4% calcareous algae. Coralline algae that they found in abundance included: *Porolithon gardineri* (Foslie) Foslie and *P. onkodes* (Heydrick) Foslie. Benthic algae in the intertidal and shallow subtidal were surveyed off Cape Kinau in 1990-92 (Hodgson and Abbott 1992). They found 124 species of algae, including 15 Phaeophyta, 20 Chlorophyta, 81 Rhodophyta, and 8 species of Cyanobacteria. Also discovered in this survey were 15 new species at the time for Hawaiian waters.

More recently, reconnaissance surveys of marine resources from Keoneoio to Kanaloa Point were conducted in 2002 by PCIRP (Basch et al. 2002) for consideration as an additional unit to the NPS. As a result of these surveys 38 species of coral across the study area with 22 species found within La Perouse Bay. Along exposed coastlines the most commonly observed corals with a high percent cover included *Pocillopora meandrina* and *Porites lobata*. In more protected areas there was generally higher species diversity with large colonies of *Pavona duerdeni*, *Porites compressa* and *Porites lobata*. A total of 112 non-coral macroinvertebrates were observed, of these, the majority (21-22 species) were echinoderms (including the COTS). Another noteworthy species observed in rare to occasional abundance included the rare black-lipped pearl oyster (*Pinctada margaritifera*). In the intertidal zone, endemic limpets (C*ellana* spp., locally known as opihi), shingle urchins (*Colobocentrotus atratus*) and aama crabs (*Grapsus tenuicrustatus*) were abundant. One hundred thirty-eight species of fish were observed. The introduced fish, Roi (*Cephalopholis argus*), taape (*Lutjanus kasmira*) and toau (*Lutjanus fulvus*) were all observed during surveys. Over 90 species of algae were observed and the list is not yet complied and will be forthcoming.

Past & Current Monitoring: Because of the challenging environmental conditions and its remoteness, little past research has been conducted in this area. Research has been restricted to Hawaiian freshwater gobies (anadromous fish). No current research is underway.

Adjacent Monitoring: The Ahihi-Kinau reserve is a part of the State of Hawaii Natural Area Reserve System and contains 807 acres as marine reserve. Marine resource survey was conducted at Ahihi-La Perouse Bays and off Cape Kinau in 1998 by DLNR (DLNR 1998) but DAR recommended further baseline surveys of marine natural resources and impact of use at two of the popular public use areas “aquarium” and “fishbowl” (DAR 2003).

Along with researchers at the Waikiki Aquarium, researchers at the University of Hawaii proposed to document the distribution and relative abundance of invasive algae throughout the main Hawaiian Islands (Smith et al. 2002, Smith 2003, Smith et al. 2004). Baseline surveys were conducted for multiple sites on Hawaii, Maui, Molokai, Oahu and Kauai. Data collected include relative abundance, habitat type, date, temperature, salinity, GPS coordinates, dominant herbivore community characteristics and any other relevant observations. More information can be found at: http://www.botany.hawaii.edu/GradStud/smith/websites/alien-overview.htm and http://www.botany.hawaii.edu/HCRI/default.htm Included in this state-wide study are Maui location at: Hana Harbor, La Perouse Bay, Kanahena Bay and Ahihi tide pools were included in a non-indigenous and invasive algae study by UH researchers (Smith et al. 2002). Of these sites, Hana Harbor had a 20% relative abundance of nonindigenous algal cover with 2 species present, Kanahena Bay had 10% cover with 1 species present, and Ahihi tide pools had 30% cover with 2 species present.

Monitoring Issues: Prevailing rough sea conditions along the coast of HALE make an active and comprehensive marine monitoring program a challenge. Any program conducted in the park would be focused primarily on intertidal monitoring during calm sea conditions. Subtidal surveys could be conducted only during calm conditions. It is likely that this work would be done through cooperative agreements between the park and other agencies such as DAR and NMFS, because the park does not and likely will not have the staff, equipment, or facilities to develop and conduct an in-house program.

Needs and Priorities: Intertidal inventories of HALE coastline are needed. The extent of use by Hawaiian monk seals of the HALE coastline is not known and could be further investigated.

KALA

Inventories: Surveys of coral reef communities off KALA were done by the the Army Corps of Engineers in the 1980s. Qualitative short-term surveys were done in 2001 for corals and fish by scientists from the Hawaii Coral Reef Assessment and Monitoring Program (CRAMP). KALA is doing a survey of intertidal organisms to develop an inventory and should be finalized on October 2004 (Carnevale and Minton in prep). Preliminary algae inventories are also underway.

Past & Current Monitoring: Presently, KALA is investigating its endemic limpet (opihi) populations to determine population status and possible fishery impacts.

The park, with NMFS, is also actively observing, protecting and managing endangered monk seals that haul out in the park; efforts include observing and tagging individuals.

Adjacent Monitoring: There are currently no monitoring programs along the north coast. However, there are monitoring programs occurring along the south coast, but are not comparative to KALA and are not included.

Monitoring Issues: Hazardous sea and coastal conditions prevail during much of the year along the coast of KALA. Any comprehensive monitoring program must account for the remoteness and dangerous working conditions at the park. KALA has the FTE available to hire a specialized professional to conduct marine monitoring and research. That position is currently vacant, and there have been difficulties in the retention of this position, resulting in a lack of consistency and development of an effective marine program in the park. KALA has obtained much of the equipment and has the facilities needed to conduct the work. KALA has the budget dedicated to marine resource management and research.

Needs and Priorities: The coral, fish and algae inventories need additional rigorous, systematic work by taxonomic specialists to be complete. Similar, comprehensive intertidal and coral reef invertebrate inventories also need to be completed.

PUHE

Inventories: An inventory of the marine algae was conducted by CPSU with 13 species observed and only two abundant species present, *Biddulphia pulchella* and *Valonia aegagrophila* (Ball 1977). The species list is limited, but it may be an accurate description of what was present at the time for this site; recent work is needed to produce a thorough inventory of algal diversity.

Fish and benthic invertebrates were also surveyed by CPSU (Cheney et al. 1977) and provide the first species listing for marine fauna in the park. Cheney et al. (1977) described the physiography and its associated marine fauna. They found 36 species of fish present, significantly less than had been observed in past studies (e.g. Brock and Brock, 1974) with weke, *Mullidichthys samoensis* the most numerous. Also commonly observed in this study were grey reef sharks (*Carcharhinus menisorrah*), black-tip sharks (*C. melanopterus*), and whitetip reef sharks (*Triaenodon obesus*).

In a more recent survey, the USFWS (1993) found in a similar habitat in Kawaihae harbor, 64 species of fish, with blacktail wrasse (*Thalassoma ballieui*), goldring surgeonfish (Ctenochaetus strigosus) and the convict tang (*Acanthurus triostegus*) as more prevalent species. Coral cover is pretty much absent in the basin, but along the extremities cover was relatively high, with *Porites lobata* the dominant species. Also observed in this area during their survey were a single crown-of-thorns seastar (*Acanthaster planci*), a triton's trumpet (*Charonia tritonis*) and a subadult green sea turtle (*Chelonia mydas*).

PICRP and partners will start to develop a comprehensive marine GIS-data base in 2003 to improve knowledge for monitoring and management of the Kona reef ecosystem structure, and to track trends in ecological and oceanographic processes, thus enabling NPS and cooperating management agencies to detect ecological changes in coral reefs in space and time.

Past & Current Monitoring: Research in the vicinity of PUHE and other sites on the Kona coast, include the recruitment processes of key coral reef invertebrates and fishes (mainly aquarium species) by NPS and collaborators that began in 2003.

NPS PICRP started work in 2003 with USGS, and contractors for aerial photography, to produce high resolution coral reef habitat classification maps for the Kona parks (PUHE, KAHO, and PUHO) and coast.

Park staff record shark sightings in Pelekane Bay. Information that they note include the number and type of shark, date and time, approximate location and position in the bay and the water column. Sighting records begin in October 1979 through present (excluding 1982 and 1990).

Adjacent Monitoring: Hawaiian Marine Mammal Consortium established a shore-based observation site overlooking Kawaihae Bay and counted the number of vessels, whales, and other Cetaceans in the area starting in 1988 (Gabriele et al. 2003).

A description of other adjacent monitoring programs can be found in the ALKA Inventory and Monitoring section.

Monitoring Issues: PUHE has no in-house staff, equipment, or facilities to conduct a marine monitoring program. Personnel, equipment, and facilities are available from KAHO and other parks. Presently, because of the low number of FTEs, the coral reef staff at KAHO cannot be expected to conduct all of the work at PUHE.

Needs and Priorities: Biologically, the natural gathering of sharks in Pelekane Bay represents an important biotic dynamic and presents a research opportunity to gather data on shark behavior. The relationships between shark concentrations, congregations of prey populations, watershed water quality, and sedimentation need to be studied. Better baseline data on shark presence and behavior is needed to monitor and manage impacts. Better understanding of the presence of sharks in Pelekane Bay could enable the park to advertise PUHO as a place to see sharks, creating a stronger visitor draw to the Park, thereby attracting those sectors of the visitor population less interested in cultural sites.

It is not known to what extent turtles or the monk seal currently use Pelekane Bay, although they have been sighted in the bay in past studies. Therefore, the use of the Bay by hawksbill and green sea turtles, and the Hawaiian monk seal should be investigated. Green sea turtles are seen fairly often at the adjacent Spencer Park.

Long term monitoring of the health of the coral reef and associated fish populations should continue.

KAHO

Inventories: A CPSU (Cooperative Park Study Unit, forerunner of Pacific Cooperative Studies Unit, University of Hawaii) technical report on an inventory of fish and invertebrates within the park was conducted in 1988 and provides valuable data but is not comprehensive as it does not include information such as the 90% presence-absence for species in the park (Parrish et al. 1990). This survey covered the high intertidal to a depth of 61 meters and fish communities and invertebrate fauna are described. Sea turtles and marine mammals are well known by park staff. Inventory work is needed and planned for corals, other invertebrates, algae and to a lesser extent, fish.

Past & Current Monitoring: A considerable amount of research on the spinner dolphins has been conducted in the past within the park. This research includes behavioral, movement, and population dynamics information on the parks “resident” pod.

The Hawaii Department of Aquatic Resources (DAR) is currently monitoring aquarium fish, a limited number of macroinvertebrate species, and coral reef fish habitat (WHAP). The park is closed to aquarium fishing, but enforcement is lacking and fishing still occurs, primarily from shore.

Marine turtle tagging and monitoring is presently underway in the park by NPS and contract staff.

Research on the recruitment processes of key coral reef invertebrates and fishes (mainly aquarium species) by NPS and collaborators began in 2003.

Adjacent Monitoring: Water quality parameters are being measured adjacent to KAHO at Kohanaiki as a part of the proposed monitoring plan for a proposed development and golf course. In addition to water quality parameters other monitoring would include biota in anchialine pools, counts and locations of all threatened and endangered species.

A description of other adjacent monitoring can be found in the ALKA Inventory and Monitoring section.

Monitoring Issues: KAHO currently has sufficient staff and equipment to conduct many components of a marine monitoring program. KAHO has a small boat, SCUBA equipment, field research tools, and some laboratory equipment. KAHO has funding dedicated to coral reef research and monitoring and has the means to obtain much of the equipment they will require for this. KAHO has limited facilities and will need additional to space to effectively conduct field operations and research.

Needs and Priorities: Inventory work is needed and planned for corals, other invertebrates, algae and to a lesser extent, fish. An inventory of cartilaginous fish occurring in the park is also needed. It would also be worthwhile to document the appearance of newly invasive alien plants and the relative cover of native and alien plants at some sites of high natural value.

Planned monitoring includes coral reef health (composition, fish numbers, and marine water quality), and the marine soundscape, focusing on low frequency anthropogenic sounds in the park. Groundwater quantity and quality are of primary concern as development around the park increases.

PUHO

Inventories: Inventories/surveys of cliff nesting birds is currently being conducted. An inventory of reptiles (including sea turtles) was conducted summer 2004 and a report forthcoming.

Past & Current Monitoring: George Balazs with NOAA has been conducting on going turtle monitoring since the 1980s. Turtles within the park are routinely tagged and monitored. An archeological survey was completed in 1964 that mapped post holes in the coastal zone.

Research offshore from PUHO, other parks and sites on the Kona coast, on the recruitment processes of key coral reef invertebrates and fishes (mainly aquarium species) by NPS and collaborators began in 2003.

NPS PICRP started work in 2003 with USGS, and contractors for aerial photography, to produce high resolution coral reef habitat classification maps for the Kona parks (PUHO, KAHO, and PUHE) and coast.

Adjacent Monitoring: UH Hilo researchers are monitoring surface and benthic water quality parameters, including microalgal communities in Honaunau Harbor. Sites surveyed and described by Doty (1969) in Honaunau Bay are being revisited and surveyed.

A description of other adjacent monitoring can be found in the ALKA Inventory and Monitoring section (below in this same section).

Monitoring Issues: PUHO currently has no in-house staff, equipment, or facilities to conduct a marine monitoring program. Personnel, equipment, and facilities are available from KAHO and other parks. Presently, because of the low number of FTEs, the coral reef staff at KAHO cannot be expected to conduct all of the work at PUHO.

Needs and Priorities: PUHO has conducted no marine resource surveys. Inventories of all nearshore marine plants and animals are needed. A coastal inventory for cultural resources is also needed.

HAVO

Inventories: Doty and Mueller-Dombois (1966) surveyed the marine shoreline bordering HAVO including intertidal areas, marine caves, and pools as a part of bioecological atlas for the park. In their characterization of intertidal communities, they found there to be three types of communities present, along with those, they provided species lists of common and dominant species, and those included those protected by coves and not affected by wave action, those moderately wave washed and those with high wave action.

Marine fish were surveyed near the Halape campsite by Ball (1976) and Major (1976). Major produced an unpublished list including 54 species. Ball documented 25 fish species, including 14 additional fish species not observed by Major. Other species documented by Ball (1976) included 106 invertebrates, and 89 species of algae.

Past & Current Monitoring: Park resource management have conducted hawksbill sea turtle nesting surveys since 1989 from June-December. The project relies on volunteers for field data collection.

Adjacent Monitoring: The University of Hawaii at Hilo has had students conducting research and monitoring projects at Kapoho as a part of their fulfillment for the Marine Option Program (MOP). These reports are available at the Marine Option Program office on the Hilo campus as well as some at the Manoa campus in Honolulu.

Monitoring Issues: Prevailing rough sea conditions along the HAVO coast make an active and comprehensive monitoring program a challenge. Volcanic activity and unstable ground conditions along parts of the coast, combined with exposed coastal environments make coastal work difficult and potentially dangerous. Consideration of any future marine monitoring efforts will depend on management information needs. It is likely that this work would be done through cooperative agreements between the park and other agencies such as the Division of Aquatic Resources (DAR), National Marine Fisheries Service (NMFS), or University of Hawaii at Hilo (UHH).

Needs and Priorities: No recent inventories have been done of HAVO coastal areas, including sea cliffs or intertidal communities. There is no recognized marine habitat within the authorized park boundaries. A comprehensive inventory of marine plants and animals is needed for these areas.

ALKA

Inventories: No inventories have been formally conducted for ALKA. They are in the process of drafting an Environmental Impact Statement (EIS) that should include a summary of significant marine resources. For the purposes of this report we are considering literature and studies that have occurred from Puakea Point down the Kona coast and over to the eastern part of the HAVO coast to Kapoho. Additionally, any of the inventories and monitoring for PUHE, PUHO and KAHO would also be applicable for ALKA. Pertinent studies that could contribute to baseline park inventory lists are numerous and provide an idea for past communities, thus could incorporate the concepts of "shifting baseline" and "ghost communities" as presented in the introduction above.

Hawaii Division of Aquatic Resources (1975) conducted a marine survey of Koaie Cove and Lapakahi on North Kohala. The survey included topography and fish counts. Ocean Research Consulting and Analysis (1978) is a reconnaissance survey for the Kawaihae small boat harbor project site and has studies that include those of coral cover, substrate type, macroinvertebrates, benthic algae and reef fish assemblages. Cheney (1977) provides a general description of physiography and marine fauna for Kawaihae Harbor. Another good source describing physiography for the West Hawaii coast coral reef resources can be found in Nolan and Cheney (1981).

Fish and invertebrate communities were inventoried by Brock and Brock (1974) along the West Hawaii coast. They found 163 species of invertebrates and 137 species of fish at 16 stations from shoreline and subtidal transects at 10m. Survey sites included (with habitat type surveyed in parenthesis) the following, moving north to south on the West Hawaii Coastline. Mahukona (tidepools), Kalala (tidepools and bay), Puako (tidepools and launching ramp), Lahuipuaa (tidepools, bay, coastline, brackish water ponds), Waiulua Bay (tidepools, bay, brackish water ponds), Anaehoomalu (tidepools, bay, brackish water ponds), Akahu Kaimu (coastline, brackish water ponds), Kiholo Bay (bay, rocky beach, embayment, brackish water ponds), Mano Point (rocky beach, subtidal), Kukio Bay (bay), Makalawena (tidepools), Keahole Point (tidepools), Kaloko (coastline, brackish water ponds), Hookena (bay, rocky beach), Kapua (tidepools), and Waialua (tidepools).

Kay et al. (1977) conducted ecological studies on marine and coastal resources in the South Kohala and North Kona reagion at the following locations: Puako Bay, Waiulua Bay, Anaehoomalu Bay, and Kiholo Bay. They provide a general description of the physiography, the hydrology, the coral community, and describe mollusk assemblages. They provide a general description of each area, with results from more specific studies on hydrology, coral communities, mollusk assemblages and a description of Wainanalii Pond. These studies were meant to provide baseline information and reference point for future development.

After the construction of Honokohau small boat harbor US Army Corp of Engineers (1983) reported on the studies conducted at five separate occasions between 1970 and 1980. Studies included those on water quality, water circulation, and plankton (Bienfang 1982); fish species and assemblages (Brock 1983); coral communities (Maragos 1983); and mollusk assemblages and echinoderms (Kay and Kawamoto 1983).

The natural history of Honaunau was described in Bryan and Emory (1986) that included a survey (with species list) of marine biota by Alison Kay. Surveys were conducted during 5 days in January and 3 days in August, 1957. These surveys were not comprehensive, but provide a general idea of the community composition of tidepools, coastline, subtidal, and shallow protected portion of the bay.

Another nearshore marine ecological study in Honaunau was conducted by Doty (1969). In this comprehensive study, the geology, hydrology & physiography were described. Additionally, surveys were conducted on the following: currents, plankton, algae, coral, mollusks, sea urchins, crustaceans, fish, marine vertebrates, and vascular plants. It provides a good source for baseline information and includes species lists and water quality parameters.

Some other studies in Honaunau include a survey of marine algae by Gilbert (1965) and Rhodes (1969) surveyed marine fauna and flora in Honaunau.

Past & Current Monitoring: WHAP, since 1998, has been studying aquarium fish in 23 sites (listed above) along the West Hawaii coast to analyze the impacts of aquarium fish collecting and the effectiveness of Marine Protected Areas (MPAs) and Fish Replenishment Areas (FRAs). In a recent publication (Tissot et al. 2004), monitoring efforts indicate that aquarium fishes were 26% less abundant in recently established FRA's than in adjacent reference areas. They recommend establishing additional MPAs throughout Hawaii as well as increased monitoring of recruitment and the effect of nearshore oceanography on recruitment.

Ecological success of alien/invasive marine algae in Hawaii: Along with researchers at the Waikiki Aquarium, researchers at the University of Hawaii proposed to document the distribution and relative abundance of invasive algae throughout the main Hawaiian Islands (Smith et al. 2002, Smith 2003, Smith et al. 2004). Baseline surveys were conducted for multiple sites on Hawaii, Maui, Molokai, Oahu and Kauai. Data collected include relative abundance, habitat type, date, temperature, salinity, GPS coordinates, dominant herbivore community characteristics and any other relevant observations. More information can be found at: http://www.botany.hawaii.edu/GradStud/smith/websites/alien-overview.htm and http://www.botany.hawaii.edu/HCRI/default.htm. As a part of this larger state-wide study, the following harbors were included: Kailua Harbor, Mahukona, Puako, Kiholo, Makalawena, Keahole, and Honokohau Harbor. Of these sites, Honokohau Harbor had a 10% relative abundance of nonindigenous algal cover with one species present, the remainder of the study sites had no nonindigenous algae present.

The Natural Energy Laboratory of Hawaii Authority (NELHA) has been funding a comprehensive marine environmental monitoring program (CEMP) off Keahole Point. Marine Research Consultants conducted monitoring for NELHA from August 1991 to May 1995 and November 1997 to November 1999. Oceanic Institute conducted the monitoring from 1995 to 1997. Data on the physical structure of the benthos, coral reef communities, and macroinvertebrate composition are collected. In the most recently published report (Dollar 2001), comparisons between communities were made with results from these surveys showing little change from earlier surveys. Dominant species in the last report was *Porites lobata* with coral cover between 42-72%. The next most abundant macroinvertebrate were sea urchins.

Hawaiian Islands Humpback Whale Marine Sanctuary Ocean Count started in February of 1996 on Oahu, with the Island of Hawaii added in 1999, Kauai in 2000, and Kahoolawe in 2002. The project covers 60 sites on these islands with over 2000 volunteers counting the number of whales observed in a four-hour period. Site locations on the Island of Hawaii along the proposed ALKA corridor include Upolu Point, Old Coast Guard Road, Kapaa Beach Park, Lapakahi State Park, Puukohola Heiau, Mile Marker 7, Hualalai Four Seasons, Keahole Point, Keahou Lookout, Honaunau Lookout, Hookena Beach Park, Milolii Lookout, Punaluu Beach Park, Kaena Point and Kahena Lookout. The most recent report found that approximately 5000 whales winter in Hawaiian waters. They also found no significant difference in trends from 2002 to 2003, that humpback whales are more abundant in February, and that they are also more abundant on the Island of Hawaii (Maldini 2003a, b).

NMFS has been conducting green sea turtle monitoring in West Hawaii since the 1980s.

CRAMP has several sites located in the ALKA corridor, including coral reef monitoring sites at Kawaihae, Nenue Pt, Laaloa, and Kaapuna. The CRAMP program was supported by NOAA through the Hawaii Coral Reef Initiative Research Program. CRAMP originated in 1997 at the University of Hawaii in cooperation with state government agencies to develop a statewide network of long-term coral reef monitoring sites. CRAMP has developed standardized coral reef assessment and monitoring methods that provide scientifically rigorous biological data for corals and fishes but not other ecosystem components, including other invertebrates and algae. Transects are at 3 and 9 meter depths which does not encompass extensive areas of reef development below these depths.

WHAP, since 1998, has been studying aquarium fish in 23 sites along the West Hawaii coast to analyze the impacts of aquarium fish collecting and the effectiveness of Marine Protected Areas (MPA) and Fish Replenishment Areas (FRA). This study aims to 1) estimate impacts of aquarium fish collecting in West Hawaii, 2) evaluate effectiveness of the FRA plan to increase aquarium fisheries, 3) to estimate critical habitat characteristics for adult and juvenile aquarium fishes, and 4) to document recruitment patterns of aquarium fishes. Surveys began in March 1999 and are conducted on a bimonthly basis. Data collected include fish densities, recruitment patterns, coral cover, abundance, diversity, distribution, and rugosity. Sites are located at the following locations: Lapakahi, Kamilo, Waiakailio Bay, Puako, Anaehoomalu, Keawaiki, Kaupulehu, Makalawena, Wawaloli Beach (KAHO), Wawaloli (KAHO), Honokohau (KAHO), Papawai, S. Oneo Bay, N. Keahou, Kualanui Point, Red Hill, Keopuka, Kealakekua Bay, Keei, Hookena – Kalahiki, Hookena – Auau, Milolii – Omokaa, and Milolii – Manuka.

The University of Hawaii Marine Option Program has monitoring sites located at Puako and at Kapoho. Students conduct senior thesis research and special projects at these locations. In addition to these sites, students have also conducted research at various sites throughout the Hawaiian Islands.

Monitoring Issues: ALKA currently has no in-house staff, equipment, or facilities to conduct a marine monitoring program. Personnel, equipment, and facilities are available from KAHO and other parks. Presently, because of the low number of FTEs, the coral reef staff at KAHO cannot be expected to conduct all of the work at ALKA.

Needs and Priorities: Once the EIS/GMP is complete, some of the needs will be documented. Some important priorities for this proposed trail include conservation and monitoring of threatened and endangered species, including Hawaiian monk seals and sea turtles.

CONCLUSIONS

Long-term ecological monitoring of marine systems is not a new concept. Several scientifically rigorous long-term monitoring programs have been operating for over 20 years. There are numerous international, federal, and local agencies or academic marine monitoring programs that comprise a diversity of objectives approaches, and techniques. The NPS (with and without partners) has conducted long-term monitoring in many ecosystems, including marine environments (e.g., Channel Islands and Virgin Islands National Parks). Rather than “reinvent the wheel” for marine monitoring, NPS must use aspects of these and other programs to develop a scientifically defensible, statistically rigorous, detailed framework for a comprehensive marine monitoring plan that yields comparable information across all Pacific Islands National Parks and other comparable areas.

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